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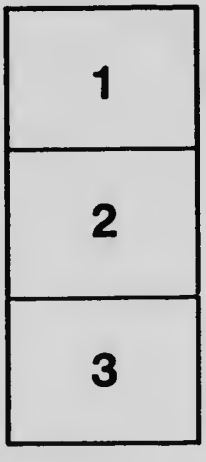

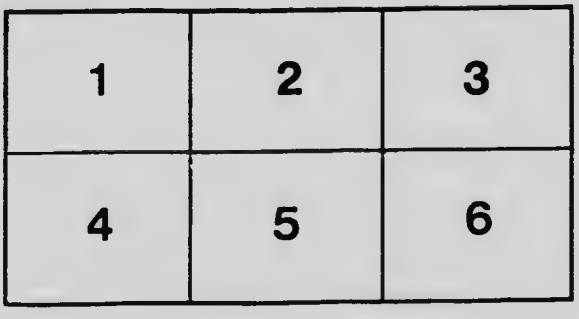

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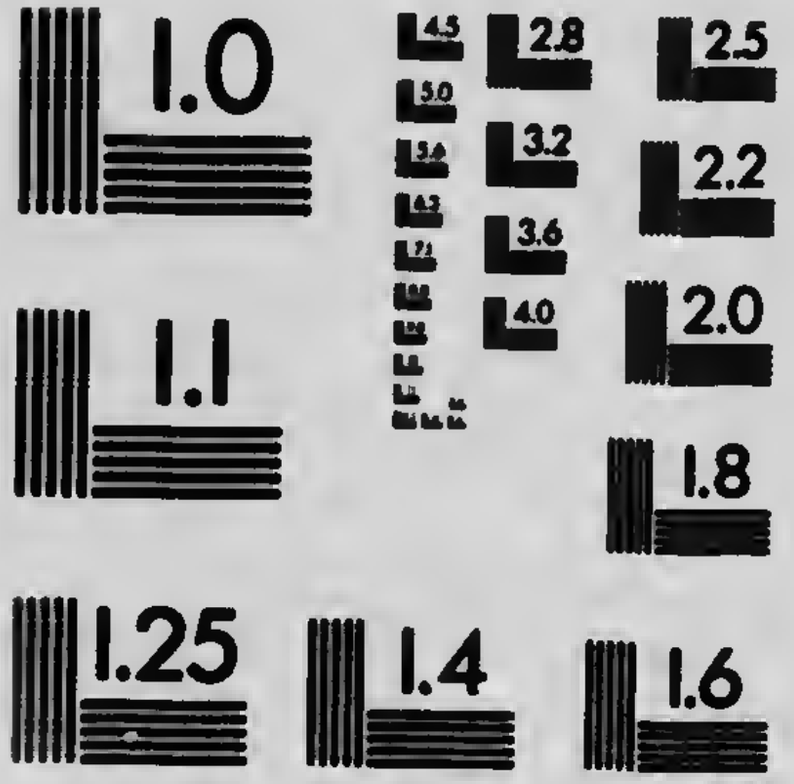

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" TWIG BLIGHT " ON APPLE.
(Blossom inoculation. Disease passing down twig.)

BULLETIN 176. [DECEMBER, '09

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE

BACTERIAL BLIGHT

Of Apple, Pear and Quince Trees.

By D. H. Jones.

INTRODUCTION.

Owing to numerous and repeated inquiries from fruit growers in various parts of the Province of Ontario regarding the cause of and remedy for the blighting of their apple and pear trees, it was decided in the spring of this year that the writer should devote as much time as possible to investigation in connection with the disease.

In accordance with this decision, the Ontario Agricultural College orchard has been under constant surveillance during the season; orchards in the Niagara, Grimsby, St. Catharines and Winona districts have been visited three times, orchards in the neighbourhood of Belleville and Pickering visited once, and numerous experiments in the College orchard and in the laboratory have been carried on.

Conditions throughout the season have proved very favourable for the investigation; the disease has been plentiful in all its stages in the various districts of the Province visited, and in the College orchard, which, at our request, was not treated for blight throughout the season, material for study has been abundant.

HISTORY OF THE DISEASE.

The disease which is known under the various names of Fire Blight, Twig Blight, Blight Canker, Pear Blight, and possibly others of local application, is of long standing on the North American continent. It has wholly destroyed many pear orchards, and has been very destructive to the apple and quince crops in nearly all parts of Canada and the United States where these fruits are cultivated.

In the volume, "Cultivation of Fruit Trees," published in 1817, which is said to be the oldest American book on fruit culture, William Coxe writes of the "fire blight which frequently destroys trees in the fullest apparent vigour and health, turning the leaves suddenly brown as

if they had passed through a hot flame and causing a morbid matter t exude from the pores of the bark."

From 1817 until 1878-80, when Burrill discovered the specific caus of the disease, many and varied were the theories advanced as to th cause. Among these may be mentioned, 1, electricity or atmospheric in fluence; 2, stroke of the sun; 3, old age or a long duration of varieties 4, sudden freezing of the bark; 5, freezing of the roots whereby absorp tion is prevented, supply of moisture cut off and the evaporation o moisture from the branches, so causing the blight; 6, too high culture 7, absence of certain mineral matters from the soil; 8, insects; 9, fungi and 10, epidemic transmitted from place to place by air. Some of thes theories still have their champions among fruit growers.

Harrison, in Bulletin 136, O. A. C., quoting other authorities, says

"In the early days of fruit growing in the Niagara district wo had n pear tree blight nor apple tree blight. With the advent of what peopl

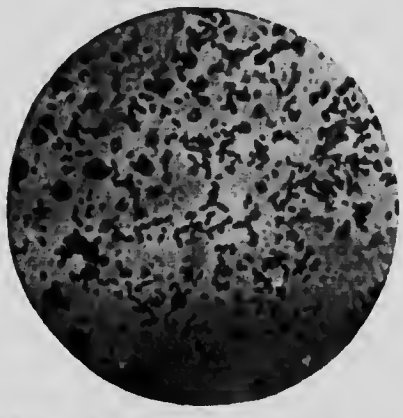

Fig. 1. *B. amylovorus*, a smear preparation made by macerating a little of the inner bark of a diseased apple twig from which the viscid liquid was oozing.
Stained carbol fuchsin X 1000.

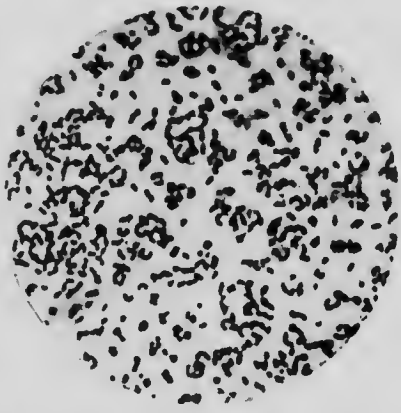

Fig. 2. *B. amylovorus*, smear stai from colony on agar four days old. Stained carbol fuchsin. X 1000

termed grafted fruit, there came, after a few years, 'blight' on the pea tree. By the year 1840 it had spread considerably. N. J. Clinton, of Essex County; S. Hunter, of Oxford; E. D. Smith, of Wentworth; Stone and Wel lington, of Welland, and R. Hamilton, of Argenteuil, reported its presence in their respective counties about thirty-five years ago. The colder parts of the province have suffered from the disease as well as the more favoured districts. The orchard of the Dominion Experimental Farm, at Ottawa, has been attacked, and the 140 Russian variety of apples cultivated there have suffered severely. In warmer districts, however, the disease has been more severe. Whole orchards have been completely destroyed in the State of Texas and certain pear growing districts in that State have been practically ruined by this parasite.

"Losses. No statistics are available to give us an idea as to the amount of loss to fruit growers from pear blight, but a few references to losses by this destructive disease will help to give us an appreciation of the subject. Coxe, in 1817, reported that he had lost upwards of fifty trees in twenty years. In the years 1826, 1832 and 1844 there was an increased prevalence of the disease, and few pear orchards escaped without partial or total loss of many trees, and some orchards were quite destroyed. Downing called it the 'monstrous malady of the pear.' Lyons stated, as the opinion of many cultivators in the State of Michigan, that, 'The pear cannot be grown with financial success on account of the blight.' Hallam, in 1882, reported that 'In Southern Illinois, pears have failed—utterly failed—so that none are now cultivated for market. The blight has destroyed the trees, branch and root;' while A. Noice, of the same State, doubted 'if one-tenth of the pear trees that are planted lived ten years on account of this destructive agent.' E. H. S. Dart stated that the severities of winter were not so much to be dreaded as the ravages of blight. He had in 1874, one to two thousand trees affected. Dr. P. A. Jewell, in 1876, lost 10,000 Tetofsky apple trees by it. Bailey, of Cornell, declared that fire blight was undoubtedly the most serious disease with which the quince grower had to contend. It is the same disease which is so

Fig. 3. *B. amylovorus* stained to show flagella; made from an agar culture seven days old.
Moore's modification of Loeffler's flagella stain. X 1000.

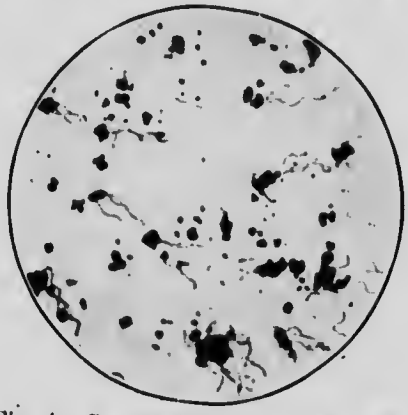

Fig. 4. *B. amylovorus* showing flagella; cells massed together in clumps.
Moore's modification of Loeffler's flagella stain. X 1000.

destructive to pear orchards in certain years and to certain varieties of apples, particularly the crabs. Selby, of Ohio, reported that the disease ranks among the most destructive known to the orchardist in his State. Chester, of Delaware, announced that pear blight was of unusual severity during the season of 1901, and caused much alarm because of its rapid spread through the orchards of the State. In 1895 its ravages in Ontario were most severe on apple trees in the vicinity of Hamilton and Burlington Bay."

Our observations this year have shown that the disease is wider spread than ever before, is continually spreading into new territory, and is causing heavier losses than formerly to the fruit growers.

From these statements it will be perceived that the blight of apple, pear and quince trees is widespread on the North American continent, and

is of long standing. If anything effective is to be accomplished in its control, extensive and radical measures must be adopted, not only by those directly interested in the production of fruits subject to its attack, but also by those authorities who have under their control the roadsides and waste places where trees subject to its attack harbour the disease. Other trees besides the apple, pear and quince, both cultivated and wild varieties, subject to the disease, are the hawthorn (*Crataegus*), June berry (*Amelanchier*), and the mountain ash (*Pyrus*).

THE DISEASE, ITS CAUSE AND APPEARANCE.

Cause.—*Bacillus amylovorus* (Burrill).

B. amylovorus is an organism averaging about 1.5 microns long and .6 microns broad. A micron is 1-25000 of an inch, therefore it would take over sixteen thousand placed end to end, or over forty-one thousand placed side by side to extend one inch. As seen through the microscope, 1-12 oil immersion lens, it appears sometimes oval in shape, sometimes almost spherical, but more often cylindrical with rounded ends. (Figs. 1 and 2.) The cells are usually single, though often in twos, seldom in threes or chains. Often, however, they are found in small clumps, the organisms evidently being matted together by the interlacing of their flagella.

They have from one to four flagella, usually only two, which are from 6 to 12 microns long and usually situated at or near the poles. (Figs. 3 and 4.) They are usually actively motile.

General Appearance of the Disease in the Tree.

The disease may occur in the bark of the twig, the branch, or the trunk of a tree and also in the fruit, more especially in immature fruit. Any one or all of these parts in the same tree may be affected, and the disease may spread from one part to another.

The disease is found on the apple tree more often in the form of twig blight, and on the pear tree in the form of body blight. Cases of body blight, however, occur in apple trees and cases of twig blight occur in pear trees. The reason that body blight is more common in pear trees appears to be because the bark of the pear tree is more spongy, thicker, and more juicy than is the bark of the apple tree; and these conditions are most favourable for the rapid and continuous development of the organism. These conditions exist in the young growth, *i.e.*, the twigs, water-sprouts, and suckers of the apple tree; and hence when the organism finds entrance to these parts the disease develops there and progresses down the affected part until it meets with adverse conditions, which it usually finds in the bark of the large branches or the trunk of the tree. And so, as a rule, it is only the young growth of the apple tree

Fig. 5. Mature apple tree (Romenskœ) badly affected with twig blight.

that is destroyed by the disease, and the tree affected survives the repeated attacks from year to year, until eventually it may become so impoverished from having its young growth annually killed that it will cease to be profitable and so call for removal. The disease, too, may find suitable conditions in the apple tree for its continued development, and in such cases we get its gradual spread in the limbs and trunk in canker form, until eventually the tree succumbs. (Fig. 36.) With the pear, on the other hand, as already stated, the disease when once it gains entrance spreads rapidly; it may destroy a tree in one season, and usually three years is the limit of life of a tree after it has once contracted the disease. (Figs. 7, 25, 26, 27.)

I.—The Disease in the Twig.

This phase of the disease is known as twig blight, or fire blight; the latter because a tree so affected looks as if it had been scorched by fire.

Fig. 6. Detail from tree shown in Fig. 5. (Note the dead, shrivelled leaves.)

It may occur in blossom twigs, foliage twigs, water-sprouts and suckers. The blossoms and leaves of affected twigs become discoloured, turning light or dark brown, sometimes red, shrivel up and die, and remain attached to the twig sometimes throughout the winter. (Figs. 5, 6, 8, 9.)

This discolouration and death of the leaves and blossoms occurs comparatively suddenly, and may occur at any time from May to September. The suddenness of its appearance is somewhat disconcerting to the fruit grower who may walk through his orchard one day and find his trees looking apparently all right, but in visiting them again a few days later he finds many blossoms and leaves dry, brown and shrivelled. This

discolouration and death of the leaves and blossoms does not mark the beginning of the disease, but rather its last stages in those parts so affected, and the disease will have been present in such twigs several

Fig. 7. Diseased Bartlett pear tree. Disease active in this tree four years; dead limbs cut away from time to time. Limb to the left died this season; limb to the right badly diseased.

days, often a week or more, before it is noticed by the casual observer. Hence, the disease is not so sudden in its onslaught as is popularly supposed.

Fig 8. Blighted apple twig; inoculation through blossoms on the two end spurs, presumably by bees. Disease passed down pedicels to spur, then to twig, killing the end of the twig. Apples developed below the diseased area, but the disease later passing further down the twig would prevent their maturing.

Fig. 9. Apple twig with two blighted spurs. These inoculated through the blossom. The disease had passed from the spurs to the twig, and when photographed the twig was girdled by the disease near the spurs and the apples and leaves at the tip had ceased developing and would soon wither.

If the bark of twigs that bear the discoloured leaves and blossoms be cut and examined the affected area will be found to be shrunken and discoloured a dark reddish brown, or purplish. Sometimes the bark will be blistered and often on such blistered areas there will be present the somewhat dried remains of a gummy exudate. This gummy exudate bursts through the blistering areas or oozes through the pores of the bark when the disease is actively progressing in an area that is well charged with sap. On first appearing, the exudate is transparent and almost colourless, but as the moisture evaporates from it, it becomes first amber colour, then brown, and finally a dark reddish brown when dry.

Fig. 10. Recently blighted pear twig. Disease very active; exudate on surface of bark. Note the small exudate globules scattered all along the stem.

(Fig. 25.) *This exudate is literally crowded with the germs of the disease,* and if by any means, either by insect, workman's tool, or careless handling of diseased parts of trees, it finds entrance to the bark of a healthy tree, there the disease will develop.

near the spurs and the apples and leaves at the tip had ceased developing and would soon wither.

below the diseased area, but the disease later passing further down the twig would prevent their maturing.

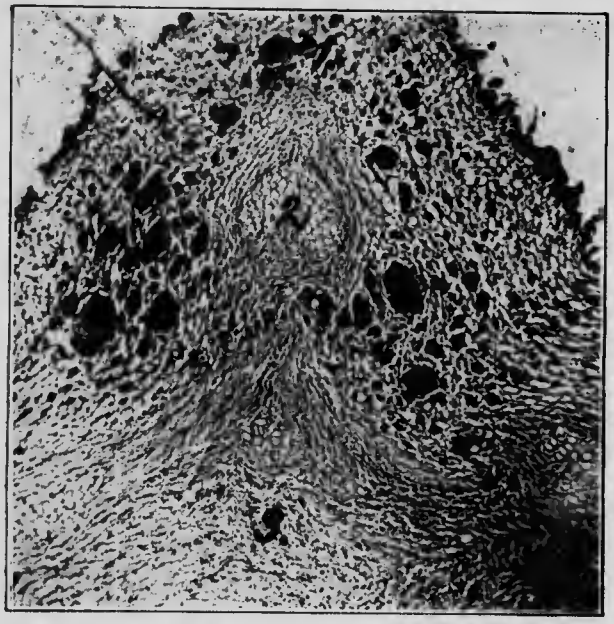

Fig. 11. Cross section of diseased pedicel of young apple. 1, bark; 2, vascular bundle; 3, wood. The darkened areas in the bark are cells surcharged with *B. amylovorus*. Section 4 microns thick, stained carbol fuchsin. X about 50.

Fig. 12. Cross section of bark of diseased apple pedicel (same section as Fig. 11), showing cells filled with bacteria within a gummy matrix. X 1000.

Fig. 13. Cross section of a diseased young apple, showing cells filled with bacteria—*B. amylovorus*. Section 4 microns thick, stained carbol fuchsin. X 1000.

Fig. 14. Cross section of a diseased young apple, showing bacteria within the cells. Section 4 microns thick, stained carbol fuchsin. X 1000.

The disease usually begins at the tip of the twig or in the blossom and works downward. The bacillus lives in the cells of the inner bark, feeds on the cell contents, and, as it develops and multiplies, passes along from cell to cell destroying the tissue as it progresses. (Figs. 11, 12.) It may travel down the twig at the rate of from a quarter of an inch to two inches a day, the rate of its progress depending largely upon the succulency of the twig and the atmospheric temperature. The more juicy the twig, the more rapid the development, and warm days are more favourable to the progress of the disease than cold days.

On reaching the base of the twig, the disease may pass into the branch bearing the twig and from this point it may progress both up and down the branch. It often girdles the branch, and when such girdling occurs the flow of sap is prevented from reaching the upper part of the

(A) (B)

Fig. 15. (a) Section of a young apple as it appeared one month after puncture inoculation with pure culture of *B. amylovorus* (see Exp. 11). The entire apple was diseased, brown, soft and saturated with a gray, viscid, slimy liquid, and teeming with bacteria. (b) Section of healthy apple (control, Exp. 11).

branch, which consequently slowly dies for lack of nourishment. (Fig. 47.) The appearance of the leaves, fruit, and bark of a branch so affected is different from that of the same parts on diseased areas themselves. The leaves slowly lose their green colour, the fruit slowly dries up, does not become decayed, soft, and pulpy, and the bark does not discolour and shrink so rapidly as does bark that is diseased. If a portion of diseased bark be stripped from the twig with a knife, the brown discolouration will be found to extend right through the bark and the surface of the wood itself is usually stained the same hue. The organisms will be found to extend in all directions within the bark some distance beyond the discoloured area.

II.—The Disease in the Fruit.

The disease is often found in immature, but seldom found in mature fruit. It may find entrance to the fruit by way of the peduncle from a diseased twig or fruit spur, in which case the disease would spread from the core outwards. Or it may find entrance by puncture of the skin by insect or other means, when the disease would work from without inward. Such cases have not been observed to be numerous, though some such were examined, and experiments in the laboratory showed that puncturing the skin of a young apple with a needle dipped into the gummy exudate from a diseased tree, or into a pure culture of the germ, resulted in the complete destruction of the fruit in from two to three weeks. (Figs. 15, 16.) Mere contact of the germ on the fruit, however, did not result in the development of the disease. Several ex-

Fig. 16. (a) Section of a diseased young pear six weeks after inoculation with a pure culture of *B. amylovorus* (Exp. 11). The whole pear was brown, pulpy, decayed, and was cut with difficulty owing to its being so soft. The entire mass was filled with bacteria. (b) Section of a healthy pear (control, Exp. 11).

periments were made to test this possible means of infection, *e.g.*, the gummy exudate, and pure cultures of the germ were copiously smeared on the surface of sound fruits, but without success.

The exterior of a diseased young apple or pear will be coloured light brown at first, then dark brown, and finally black. (Fig .) As the disease progresses, the flesh will become soft and pulpy, and the skin will become somewhat wrinkled. (Figs. 15, 16.) If the fruit be sectioned, the diseased part of the flesh will be soft and present a slimy and decayed appearance, discoloured any shade of brown to black. Microscopic smear preparations of this broken down tissue or of the slimy fluid reveal dense swarms of the bacillus, and paraffin sections show the

cells to be impregnated with the germ. (Figs. 13, 14.) Sometimes this slimy liquid oozes through the pores or through insect punctures of the skin in the same way that the gummy exudate emerges from the diseased areas on the twigs, limbs or trunks of the trees. When so exposed, insects alighting on the fruit get contaminated with it, and, as it is crowded with the disease germs, when the insects fly away they carry the germs along with them, especially on their feet and mouth parts. The disease spreads rapidly in the tissue of a young fruit, but slowly in a fruit that is ripening. In the latter case the diseased area does not become slimy, soft and pulpy, but becomes discoloured brown, having

Fig. 17. Two halves of a diseased pear forwarded to the laboratory for examination. The flesh was brown, viscid, soft, and filled with *B. amylovorus*. Evidently the pear had been punctured and inoculated when young by some insect, within the sunken decayed area shown on the right half. Note the slimy liquid smeared on the background and trickling down from the stems. This was swarming with *B. amylovorus*.

somewhat the appearance of a bruise, but the discoloured tissue is not tough as is that of bruised tissue. (Figs. 18, 19.) As the spur, twig or branch bearing the diseased fruit dies from the disease, thus preventing the flow of sap to the fruit, such fruit slowly dries out, becomes deeply indented with wrinkles, turns black or dark gray, and dull, and becomes quite hard. Such fruit will often remain on the tree through the winter.

III.—The Disease in the Main Limbs and Trunk.

1. In the Apple Tree. Where the disease occurs in the main limbs or trunk of the apple tree it is usually confined to a well-defined and limited area. (Fig. 37.) This is the phase of the disease called by Whetzel "Blight Canker." Fully 90 per cent. of such infections are due to twigs, water-sprouts, and suckers being primarily inoculated. (Figs. 20, 21, 22, 23.) Down these latter the disease progresses until it reaches their base from which it usually spreads in all directions within the bark of the larger growth. So long as suitable conditions are obtained in the older growth, the disease will continue to spread there.

Fig. 18. Section of a diseased ripe apple forwarded to laboratory for examination from British Columbia. The brown discoloured areas were not slimy, but were filled with *B. amylovorus*. Most of these diseased areas were near the outside, and externally the apple presented the appearance of being badly bruised. The shipper stated that a considerable number of so affected apples were in his district. Evidently it had been inoculated by insect punctures.

While the disease is active, the bark affected will usually be a little darker in colour than the healthy bark and will usually appear somewhat moist as if water soaked. Sometimes it will be slightly raised and, if there be plenty of sap in the bark, it will usually blister and the characteristic gummy matter loaded with the germs will exude. As

soon as unfavourable conditions obtain, as, for instance, a diminution of the sap supply which may be induced by lack of cultivation, drought, or cold weather, the progress of the disease is checked, the germs present consume all the food material in the affected area, and being unable to get more owing to the resistance of the surrounding tissue to their invasion, they gradually die out from lack of nourishment. When the disease ceases to be active, the affected bark shrinks and subsides, and in doing so it is torn from the healthy tissue surrounding it and a crack is thus formed, usually entirely encircling the dead portion.

Fig. 19. Section of a ripe Tolman Sweet apple, O.A.C. orchard. The dark areas near the centre were brown and filled with *B. amylovorus*. On the outside of the apple was a brown, somewhat sunken area, 2 in. x 1½ in. Part of this area was glazed over with a dry, gummy exudate, a large drop of which was still moist and adhering to the surface; this contained many bacteria. From this area the diseased tissue spread irregularly to the core.

When cut with a knife the diseased bark will appear brown, while the healthy bark surrounding it will be pale green or creamy white in colour, and the line of demarcation between these is usually sharp and distinct. The dead bark is very tough. Sometimes germs will have pushed beyond the well-defined cankered area and will remain alive but not very active in the apparently healthy tissue until favourable condi-

tions once more obtain, when they will resume their activity and another cankered area surrounding the old one will thus be produced. Sometimes a series of such cankered areas will develop, due to a repetition of the necessary conditions for growth, each crack separating one cankered area from the others representing the termination of a period of activity. Blight canker may develop at the base of the trunk, or crown, from infected suckers. One such case occurred in the College orchard this season.

2. In the Pear Tree. As above intimated, while the disease does not cause so much loss by its development in the bark of the trunk and main limbs of apple trees as it does in the twigs and smaller branches of the same, with the pear it is the reverse conditions that prevail.

When once the germ finds entrance to the bark of a main limb or trunk of a pear tree, it seldom dies out until the whole tree is dead,

Fig. 20. Typical blight canker at the base of a water-sprout on the main limb of an apple tree, O. A. C. orchard. The water sprout had been inoculated by aphids coming to it from a diseased tree.

unless the diseased area is radically removed. (Figs. 7, 43.) Especially is this the case with the choicer varieties of pears—the Duchess, Bartlett, Flemish Beauty, Clapp's Favourite and Clairgeau, for instance. When once these trees are attacked they seldom live more than three years if the disease is allowed to have its way. It is generally recognized by pear growers, both in Canada and the United States, that the cultivation of these superior varieties of pears results in a dead loss to them financially because of the blight; hence their cultivation is very little practised any

Fig. 21. A blight canker, 16 in. x 9 in., at the base of a cluster of water-sprouts on main limb of a Tolman Sweet, O.A.C. orchard. The water sprouts were inoculated by aphids.

Fig. 22. Blight canker on apple twig at the base of a fruit spur which had been killed by the disease after being inoculated through the blossoms, O.A.C. orchard.

more, and such varieties as the Kieffer, which in texture and flavour is something akin to a turnip, and is not juicy enough for a bacillus to readily thrive in, is produced and put upon the market.

The disease develops and spreads in the main limbs and trunks of pear trees in much the same manner as in the twigs. The germ lives in the tissue cells of the bark, feeding on the cell contents. The exterior of the bark becomes discoloured, sometimes brown and sometimes purplish. It often blisters and cracks and amber-coloured gummy exudate emerges when the disease is most active. (Figs. 24, 25.) This may often be seen flowing slowly down the face of the diseased area. The disease is much less active during the winter than during the summer, though the complete cessation of its activity during the cold period

Fig. 23. Large blight canker rapidly spreading in crotch of main limbs of Romenskœ apple tree, O.A.C. orchard. The whole of this canker developed in two months after inoculation by aphids through a water-sprout. Just above the centre of the picture is a small canker spreading at the base of a water-sprout also inoculated by aphids; and at the extreme right may be seen a long narrow sunken area running down the limb; this is a portion of a large canker formed at the base of a water-sprout, also aphid inoculated.

is questionable. In the spring the tissue surrounding the dead cankered areas is teeming with the disease germs, which, on the flow of sap, begin rapidly to develop and spread farther afield. The disease is irregular in its progress. It may spread in any direction, and the cracks mark its periods of activity, and may be longitudinal or horizontal, but are seldom oval or circular as in the case of the apple. These periods of activity vary in duration, depending somewhat upon

Fig. 24. Main limbs of a Flemish Beauty pear tree, O.A.C. orchard, in which the blight is rapidly spreading. The limb to the right is practically dead. Notice the cracking and blistering of the bark, especially on the middle limb. All the disease above the crotch developed this season from the cankered area below the crotch. It spread throughout the bark very rapidly during June, July and August. Photo taken in September.

climatic and soil conditions which regulate the flow of sap—more sap, more disease, if the germ be in the tree.

It is this fact that is responsible for the idea that so largely prevails among pome fruit growers, that orchards under cultivation are more subject to the blight than are orchards in sod. The trees in orchards that are fertilized and cultivated naturally produce more young growth, and are more sappy than those in sod, and this condition being the most favourable for the rapid development of the organism, should it be present in the trees, the spread of the disease in these trees

Fig. 25. Main limbs of blighted Flemish Beauty pear tree, showing the amber-coloured gummy liquid exuding from and trickling down the surface of the cankered area.

Fig. 26. Winter aspect of same tree as represented in Fig. 27. Note the leaves and fruit still adhering to limbs killed by the disease.

is much more noticeable than in trees that are less thrifty. Pear orchards may be in sod a number of years and the disease be present in the trees, but progressing so slowly as to be scarcely noticed by the owner. At length the owner decides to plough up the sod and cultivate. This results in the greater flow of sap in the trees, produces ideal

conditions for the rapid development of the disease, and before the season is over dead limbs and dead trees are seen in all directions. The owner, disgusted, destroys the dead material and allows the orchard

Fig. 27. Blighted Flemish Beauty pear tree, summer aspect. A dead limb was cut from the stub seen on the right in the spring. The dead limb to the left produced leaves this season which fell in June, owing to the complete girdling of the limb by the disease. The disease spread rapidly up the middle branches, which are those represented in Figs. 24 and 25.

to return once more to sod, deeming it better to have a decreased yield of fruit than to have his trees killed out wholesale. The spread of the

disease slowly subsides, falls to proportions in which it is not very noticeable, and the owner decides that the attack of the disease was due to the cultivation, which, of course, indirectly it was. A number of such cases have come directly before our notice.

Sod, however, is not an ideal condition for an orchard. It means a diminished supply and an inferior quality of fruit, and it is a nursery for numerous of our insect pests. This being the case, what is the pome grower to do? The best thing is to find a more direct method of attacking the blight than merely diminishing its spread by leaving the orchard in sod. If we can only find out the exact means whereby it is spread, and then directly, instead of indirectly, attack those means, we shall be in a fair way to a successful control of the disease. Our observations this season have resulted in establishing two specific agents in the spread of the disease—the aphis, *Aphis mali* and *Schizoneura lanigera* in the apple, and the fruit bark borer, *Scolytus rugulosus,* in the pear.

DISSEMINATION OF THE DISEASE.

The specific cause of the disease once being established, the next step is to find out its means of dissemination. Numerous theories concerning the spread of the disease have been promulgated both by scientists and by laymen. Mere theories, however, while they may be plausible are not by any means satisfactory, and unless substantiated by direct observation data are not reliable.

Some observers contend that the wind is responsible for much of the spread. They noticed that the disease progresses through the orchard in the direction of the prevailing winds. They have suggested that the gummy exudate dries on the outside of the tree, powders into dust, and in this condition is blown from tree to tree. While the argument sounds plausible, it has not been verified by experiment. Spores to enable it to tide over unfavourable conditions have not been observed in the organism under any conditions, and the organism soon dies on drying in the sun, as we have proven both in the laboratory and by outside observations.

Blossom Inoculation. So far as observed, insects are the principal means of dissemination. Nearly all the twig blight that is noticed in the spring is due to blossoms being infected. Bees, wasps, and other insects visiting the blossoms are said to convey the germ from flower to flower. Waite, of the United States Department of Agriculture, has found the organism in the nectaries of apple blossoms and also on the legs and mouth parts of bees. This evidence is sufficiently conclusive to warrant the statement regarding bees as carriers of the disease.

The question is, where do the bees in the first place get the contamination? As previously remarked, when the disease is in an active condition either in twig, bark or fruit, a gummy exudate loaded with germs is often found oozing through the epidermis of the affected part.

Insects alighting upon or feeding on this material would get contaminated with the germ and carry it away with them attached to their feet

Fig 28. Blighted water-sprouts from an apple tree, O.A.C. orchard. These were inoculated with the disease by aphids. Note the remains of the aphids all over the twigs, and especially the winged aphids on the leaf to the left ready to fly off to another tree, carrying the germs of the disease with them. Pure cultures of the germ were obtained from these.

and mouth parts particularly. We have found flies, beetles, aphids and other hemiptera feeding on or walking over this area. Though possibly

this is how the bee gets contaminated in the first place, the writer has never yet seen one alight on the gummy exudate, and in fact though careful search was made last season through the College orchard all through blossom time, no gummy exudate could be found on twig, branch or trunk of apple or pear tree. Later in the season, however, in the latter part of June, throughout July and August, when the disease was active, much exudate was observed on trunk, twig and branch of affected trees, and many trees were affected.

Notwithstanding the fact that no exudate was observed on the trees before or during blossom time, a large number of blossom infections occurred and subsequently developed in various parts of the orchard. If these inoculations were made by bees, from where did the bees get the germ, if there was no gummy exudate for them to come in contact with? We expect to work more on this phase of the subject next season if possible.

So much, then, for blossom infection. The germ has been found in the nectaries of the flowers and has been found on the proboscis of bees visiting these flowers. But the germ will not develop in the nectaries until it is deposited there. Here our positive knowledge of this phase of the subject ends.

Twig Inoculation. The term twig inoculation is here applied to twigs affected by means other than through the blossom. It seems to be generally thought that all twig infection is through the blossom. The writer concludes thus as he has not seen any reference in literature dealing with the disease that says anything to the contrary. For several seasons we have casually noticed in various parts of the country numerous twigs affected that had no blossoms on them, or in some cases anywhere near them. This was particularly so in the case of apple trees. The question arose in our minds as to how these twigs became infected.

During the past season this phase of the disease was first noticed on July 1st. The first specimens observed were a few water-sprouts on the main limbs of a mature Spy apple. The tree was in sod, had been well scraped over the previous fall and sprayed during the spring. No disease was found on any other part of the tree than on these water-sprouts. How did it get there? There were no blossoms on the sprouts as they were largely of this season's growth, hence it was improbable that bees had caused the inoculation. The means of inoculation, however, were readily apparent. *The sprouts were covered with aphids and aphid remains.* The tips of the sprouts that were dead were covered with the remains of aphids, and the leaves and stems that were still alive were dying from the disease and were covered with living aphids, and many of these were of the winged form. The sprouts were taken to the laboratory, photographed (Fig. 28), and pure cultures of the germ were obtained from them.

Every horticulturist is more or less familiar with the aphid and its injuries to trees. The aphid is a sucking insect. It obtains its food by puncturing the tender bark of young shoots and leaves with its

Fig. 29. Cluster of water-sprouts on apple tree in which the blight is rapidly spreading, being carried from twig to twig by the aphids.

Fig. 30. Water-sprouts on apple tree in similar condition to those shown in Fig. 29.

proboscis through which it sucks the plant juice. It reproduces very rapidly. Hitherto it has been thought that the extent of the damage which it caused was confined to the direct injury done to the plant by depriving it of sap and the malformations caused by the irritation set up in the area attacked. Our observations this season, however, have proven conclusively that the great majority of the new infections of twigs by the blight after the blossom season has closed are due to the transmission of the germ from diseased areas by aphids.

In the College orchard are over three hundred apple trees, and more than one hundred pear trees, and these were under close surveillance all through the season, and numerous other orchards about the Province were visited. In all instances the same facts were elicited. We will cite a few individual cases.

Fig. No. 29 is a Tolman Sweet apple tree in the College orchard. Previous to the arrival of the aphids early in July there was no blight on the tree. During July the aphids (*Aphis mali*) were very numerous on the young growth of this tree, as they were on many others in the orchard. The tree was frequently examined and the spread of the disease was coincident with the spread of the aphids about the young growth. In a number of cases the disease entered the limb at the base of the water-sprout and there formed a small canker. The water-sprouts being very tender and juicy, they formed an ideal feeding ground for the aphids and were also an ideal medium for the rapid development of the disease when once inoculated. Within a week all stages of the disease were evident. Some sprouts were brown, shrivelled, and dead with dried gummy exudate and the remains of aphids still adhering to them. In others the disease was very active. In practically every case it had commenced at the tip, evidently the first part attacked by the aphids, for invariably it was there that the remains of aphids occurred in abundance, while the living specimens were to be found further down the sprout. The tips of such would be dark brown and shrunken and curling over, while further down the gummy matter would be often noticed exuding, and this on frequent microscopic examination, revealed the germs in characteristic abundance.

Fig. 31 represents a Tolman Sweet stock on which were a number of grafts of different varieties. These grafts were three years old, and had developed a dense bushy growth of twigs. Previous to the arrival of the aphids at the end of June, there was no blight on the tree. Soon after their advent the blight appeared, and as they increased in numbers and spread over the tree the blight spread also, until at the end of August fully ninety per cent. of the young growth was killed out by the blight. In several cases the disease had entered the stock, and in one instance a canker four inches by six inches had developed by September. In addition to the top of the tree being killed out, the whole of the dense sucker growth at the base was destroyed by the blight, not one single sucker being left alive. Fig. 32 represents the tree on September 10th when the dead tissue was cut away.

Fig. 30. Shoot of water-sprouts on apple tree in which the blight is rapidly spreading, being carried from twig to twig by the aphids.

Fig. 30. Water-sprouts on apple tree in similar condition to those shown in Fig. 29.

Fig. 31. Tolman Sweet stock on which numerous grafts had been made. Note about 95 per cent. of twigs blighted.

Fig. 32. Same tree as shown in Fig. 31 after having the diseased material cut away in September.

Fig. 31. Tolman Sweet stock on which numerous grafts had been made. Note about 95 per cent. of twigs blighted.

Fig. 32. Same tree as shown in Fig. 31 after having the diseased material cut away in September.

Fig. 33. Young apple tree, Vandevere, showing blighted twigs, all of which were inoculated with the disease by aphids during June and July.

Fig. 34. Same tree as shown in Fig. 33, with the diseased twigs cut away in August in order to save the tree.

Fig. 33 represents a young Vandevere apple tree four or five years old. No blight was on this tree before the aphids settled upon it. With their arrival the blight commenced, and by the first week of August fifty per cent. of the young growth was killed out. At this date, in order to preserve the tree, the diseased tissue was cut away, and Fig. 34 represents the tree after such pruning.

Fig. 35 represents a Benoni apple tree that had . . . oms this season. No blight developed on it until July when it . . . attacked by

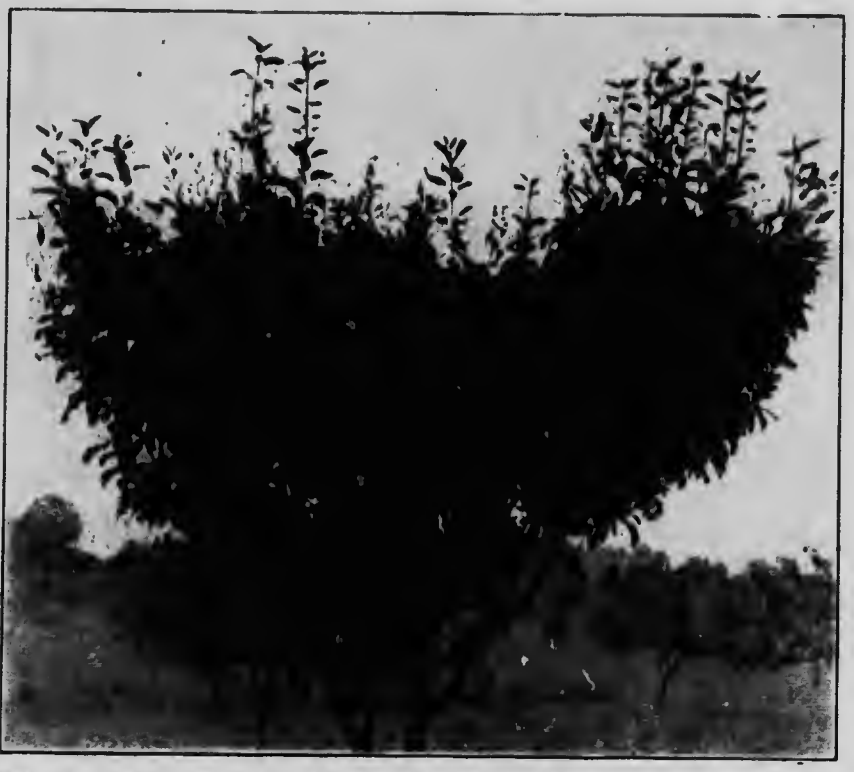

Fig. 35. Head of a Benoni apple tree in which 50 per cent. of the twigs blighted after being inoculated with the disease by aphids.

aphids on the water-sprouts near the base of the main limbs. Here the disease first developed. The tree had been pruned cup-shape to allow the light to get in to the interior. By the middle of August more than a hundred twigs, all of which were on the inside of the tree, were blighted. The aphids had passed from twig to twig on the inside of the tree and carried the germs of the disease wherever they went. All the sucker growth at the base of the tree also developed the blight after being attacked by the aphids.

Fig. 21 represents a canker on the main limb of a Tolman Sweet apple tree that developed this season at the base of a cluster of water-sprouts after these were attacked by aphids. The disease passed down the sprouts into the bark of the limb, and the limits of its most active period are readily distinguished by the encircling crack which separates the dead from the living tissue.

Dozens of such cankers were examined and all traced to a similar beginning.

Orchards in the Niagara, St. Catharines, Grimsby, and Winona districts were examined where similar cases in abundance were observed.

A mature apple orchard at Fruitland belonging to Mr. J. Tweddle was examined on September 14th. Mr. Tweddle had taken great pains to remove all blight during the pruning season. The trees had been well sprayed with Bordeaux in the spring and early summer and were in splendid condition. In the examination scarcely any blossom infection was apparent, but dozens of trees were found on which water-sprouts and this season's twig growth had been killed out by the blight, and all these upon examination bore evidence of aphids, and in many cases the woolly aphis (*Schizoneura lanigera*) was still present in considerable numbers, clustered in the axils of leaves and fork branches and in crevices of the bark. In all probability, the aphids had in the first place come in contact with the disease in the environs of the orchard, for the blight was prevalent all through the district, not only on the fruit trees in the orchards, but we observed it on the hawthorn bushes along the roadsides as well.

Spread of the Disease in the Nursery.

In the apple nursery of Mr. E. D. Smith, Winona, there were some thousands of young seedlings. Very few of these were affected with the blight. A dozen or so cases were observed, but the percentage was very low. On being questioned concerning the prevalence of aphids among the nursery stock, the manager stated that owing to constant supervision the aphids had very little chance to make headway. Kerosene emulsion was always on hand, and as soon as aphids were noticed on the stock, every young tree affected was immediately dipped in the emulsion. Hence, by keeping the aphids in check the disease had been kept from spreading in the nursery. The disease was prevalent in the immediate vicinity of the nursery in every direction. At one end of the rows of apple seedlings was a bunch of about two hundred young Kieffer pear trees heeled in ready for transplanting. Every one of these was badly blighted, the majority being rendered totally worthless, and the manager said that nothing could be done with them other than to burn them all just as they stood bundled together. At the other end of the rows ran the public road, and on the opposite side of the road were apple trees very badly affected with the blight, and hawthorn trees

Fig. 36. Wound on main branch of a Romenskoe apple tree where the bark, after being cankered and killed by the blight, has been cut away to save the tree. The exposed wood was painted with a thick coat of white lead to prevent entrance of saprophytic fungous spores.

Fig. 37. Old blight-cankered area on limb of Romenskoe apple branch. This canker extended three feet eight inches along one side of the branch, almost girdling it in two places. The dead bark was shelling off. In places saprophytic fungi had found entrance to the heart wood, thus hastening the decay of the branch.

also similarly affected. So that the absence of blight among the apple seedlings was not due to there being no blight near them, but rather to the destruction of the means of transmission, *i.e.*, the aphids, as soon as they appeared.

At other nurseries that have come before our notice, little, if any, attention was paid to the aphids, which were abundant, and in these nurseries blight was excessive.

From our observations we have concluded that practically all the fresh nursery infection, all the water-sprout infection, all the sucker infection, all the twig infection other than that due to blossom inoculation, on the apple trees was due this season to inoculation by the aphis, and we infer from this that probably it is usually so. This season the aphis was very plentiful and the blight was proportionally so. Possibly the periodic bad outbreaks of blight in the apple are coinciden' with a plague of aphids such as occurred this year.

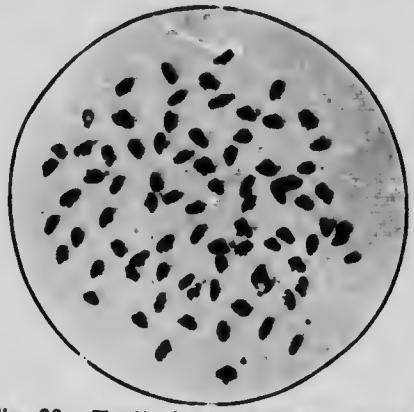

Fig. 38. Fruit bark boring beetles (*Scolytus rugulosus*) picked off the bark of a diseased Bartlett pear tree, the tree shown in Fig. 7, the bark of which was badly riddled with their shot-hole borings. (Natural size.)

Fig. 39. Agar plate cultures of bacteria which developed in the track of the fruit bark boring beetle seen natural size in the upper left hand of the picture. About 65 per cent. of this bacterial growth was *B. amylovorus*. The beetle was obtained from a blighted Bartlett pear tree with sterile forceps.

Spread of the Disease Among Pear Trees.

The aphis, however, is not found to any extent upon the pear tree. On the other hand, as already stated, neither is twig blight very common on the pear except where it occurs as the result of blossom inoculation, and this is not nearly so common as on the apple. How, then, is the disease carried from tree to tree in a pear orchard?

Any boring beetle or any biting or sucking insect frequenting pear trees may act as carriers of the disease. We have been able to trace to

one species of the boring beetles, *e.g.*, the fruit bark borer (*Scolytus rugulosus*), several cases. While inspecting a diseased young Bartlett pear tree in the College orchard one bright sunny day in June, we noticed a number of fruit bark borers emerge from their holes and run about on the surface of the bark. Some of these were caught in sterile test tubes and brought to the laboratory. Several gelatin and agar plates were prepared and when set, one of the beetles was allowed to run about on the surface of each. The plates were then incubated. All of them produced copious bacterial growth along the tracks of the beetles. Of this growth, from thirty to seventy-five per cent. was of the blight germ, *Bacillus amylovorus*. One of these plates is represented in Fig. 39.

On another ocasion, the 16th of September, while examining the pear trees in Mr. E. D. Smith's orchard at Winona, we met with the same species of beetle in healthy young growth on a mature Bartlett

Fig. 40. Cuttings from a healthy Bartlett pear branch that was perforated immediately below each of thirty leaf or fruit spurs by the fruit bark boring beetle. In every hole was a beetle and the bark surrounding the eight represented was developing blight. (Natural size.)

pear tree. On the under side of thirty out of forty leaf spurs on the branch were the characteristic round shot-hole borings of *Scolytus rugulosus*, and in nearly every hole was an adult beetle. In the region of eight out of the thirty punctures, the blight had slightly developed with the characteristic changes in the bark. About eighteen inches further down the branch from the last of the series of punctures in the healthy part of the limb was a small cankered area in which were also two borings of the same nature. Whether this cankered area was the result of inoculation by the beetles making the borings, or whether the borings had been made subsequent to the development of the canker

Fig. 41. Dead branch from a Bartlett pear tree, killed by blight, showing the borings of the fruit bark boring beetle. (Natural size.)

Fig. 42. The same branch with a portion of the bark removed to show the white larvæ in September. (Natural size.)

Fig. 43. Young Bartlett pear tree killed by blight. The branches shown in Figs. 41 and 42 were taken from this tree.

was not decided. The canker, however, was in an active condition and was of recent development. The tree was otherwise free from disease.

On making another examination of the afore-mentioned Bartlett tree in the College orchard (Fig. 43) on September 20th, it was found to be practically dead. Nearly all the leaves had fallen, and what remained were pale yellow or brown. The tree had suffered badly from the blight in the trunk the previous season, which had so lowered its vitality that the foliage this season never looked healthy and vigorous, and as the disease continued to spread in the trunk this spring and early summer the tree gradually succumbed. During this time the beetles had made numerous perforations in the bark of the trunk and larger limbs, and Fig. 41 is a representation of one of the latter. Fig. 42 is a representation of the same portion with some of the bark removed. Here

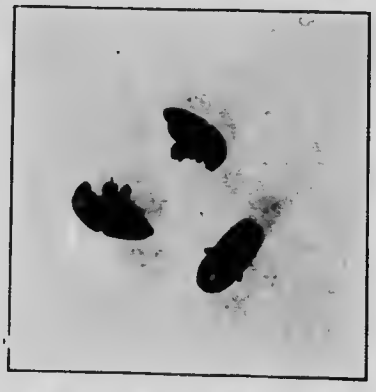

Fig. 44. Fruit bark boring beetles (*Scolytus rugulosus*) enlarged.

are seen the larvæ of the beetle. These larvæ were numerous in different parts of the tree.

Dr. Bethune and Messrs. Jarvis and Caesar of the Department of Entomology, O.A.C., were interviewed for information regarding the beetle, its habits and occurrence. They stated that it is very common on, and destructive to, both sour and sweet cherry trees, peach, plum, and apple trees, but they had not noticed its prevalence on pear trees. In the case of the cherry and peach trees it attacks them often in great numbers, causes a plentiful discharge of gum from the perforations, and often results in the destruction of the tree. This gum is very noticeable on the cherry and peach trees attacked; in fact, it was its presence which caused the investigations that finally led to the discovery of the beetle as the origin of it. In the case of the beetles' attack on the pear trees observed, there was absolutely no sign of any gummy material except where the blight was active in the bark. And, in every instance where

the beetle occurred in the healthy bark of a branch it was on the under side of a leaf spur, and the perforation was so small that one had to look carefully to perceive it. Possibly for this reason it has largely escaped the observation of entomologists.

Chittenden, in Circular No. 29 of the United States Department of Agriculture, 1898, states regarding the fruit bark boring beetle that, "In addition to the trees already mentioned as subject to its attack, available data indicate that pear is also quite subject to infestation, and apricot, nectarine, and quince trees are known to have harboured this species, while in Europe the mountain ash and the hawthorn are also recorded as being subject to its attack."

In Bulletin 19, new series 1899, of the United States Department of Agriculture, Division of Entomology, occurs the following on the fruit-tree bark beetle:

"May 16, 1898, Prof. E. A. Popenoe wrote from Topeka, Kansas, that in search for trees attacked by this species in different portions of Kansas many rows of trees were examined, and *in nearly every tree affected the top was blighted or a stump remained whence a blighted branch had been cut.* Beetles were also noticed in pear trees whose leaves were coloured so as to indicate ill health and were found to be also diseased at the root below the budding point. Many of the diseased trees showed the beetles just beginning work, precluding the possibility of the appearance of the disease resulting from the beetle attack. *In a few trees, however, the beetles were found at work where there was no sign whatever of ill health in the tree attacked.*"

Popenoe was studying this species of beetle and not the blight, and he found the beetles more often in diseased trees than in healthy ones. But he did find them in healthy ones. He found also that nearly every tree affected by them was blighted. He evidently concluded that the spread of the blight was responsible for the spread of the beetles. May not the reverse of this be true, *i.e.*, the spread of the beetles responsible for the spread of the blight. In the light of the above observations and experiments we venture to think that it may. There is, however, much room for more investigation on this part of the subject.

The facts, then, concerning the fruit bark boring beetle (*Scolytus rugulosus*) as a means of spreading the blight in pear orchards, are:

1. It has been found within and beneath the bark of both diseased and healthy trees.

2. Beetles caught issuing from their burrows in blighted trees have shown the presence upon their bodies of immense numbers of blight organisms when they were allowed to walk over the surface of gelatin and agar plates. Fig. 39.

3. Beetles have been found in what was to all appearance, sound, healthy, vigorous pear bark before their entrance, but which has developed a limited though spreading blighted area in the immediate vicinity of their boring.

We conclude, therefore, that the fruit bark boring beetle (*Scolytus rugulosus*) is one means of spreading the blight in both apple and pear

trees. As the blight is also common on the mountain ash, hawthorn and Juneberry, three other trees subject to the attack of the beetle, it is possible that the beetle is responsible for some of the disease there found.

Other Means of Spreading the Disease.

The pruning-knife, saw, chisel, shears or other workman's tool used in the orchard, after having come in contact with a diseased tree is a very potent carrier of the disease. We have proved this experimentally by using a knife and a saw on the diseased part of a tree and then on a healthy tree, nicking the bark or cutting off branches, and in about seventy-five per cent. of the experiments the healthy tree contracted the disease at the point where cut. Both pear trees and apple trees were so experimented on.

Scraping healthy trees with diseased trees when removing the latter from the orchard usually results in infection of the former. A striking instance of such infection came before our notice in the orchard of Mr. E. D. Smith, Winona. While making an inspection of the orchard in company with the manager we noticed a mature Bartlett pear tree standing isolated, no pear trees being anywhere near it. Just one of the lower limbs of this tree was blighted, and the foliage on this limb was dark brown or rapidly turning that colour. All the other foliage on the tree was bright green, vigorous and healthy, and no other sign of blight was observed on the tree. On making a close examination of the affected limb, we noticed that the underside of the lower extremity was bruised, some of the bark having been torn away, and this was the centre of the diseased area. When the manager was asked how long he thought it might be since the bruise had been made, he said it looked as if it had been done the fall before. When asked if there had been any diseased trees near, against which a waggon might have bumped and thus become smeared with the germ and then rubbed against the healthy tree, thereby inoculating it, he replied that the year before, the tree formed one of a row of Bartlett pears, and that all but it, which was the end one of the row, had developed the blight very badly, and in the fall all the diseased ones had been hauled out. Here then, evidently, was the means of infection. One of the diseased trees in being hauled past the healthy one had scarred this one limb, and left some germs in the wound. These penetrated the bark tissue, wintered over, and developed the cankered area during the summer, finally girdled the limb, and this cutting off the supply of sap to the upper part caused it to turn brown and die as described.

ERADICATION AND PREVENTION OF THE DISEASE.

The eradication of a bacterial disease from a district, whether it be a disease of man, animals, or plants, usually appears to be a difficult matter. The difficulty, however, is limited to the taking of necessary precautions to ensure a thorough destruction of all the germs of the

disease within that district. The precautions necessary to prevent the spread of and to destroy the germs of such diseases as cholera and typhoid fever in man, anthrax in cattle, hog cholera in swine, are now familiar to almost everybody. Of course, it means a great deal of work and trouble for those concerned, but this positively cannot be avoided, and the effectiveness of the work is proportionate to the thoroughness with which it is conducted.

The apple and pear blight at present is confined to the North American continent. No cases have ever been reported from any other country. Arguing from the point, no germ, no disease, what is needed to stamp the disease out of existence is simply to destroy all the blight germs in the country. This, however, is practically an impossbiility, for the necessary concerted action on the part of all those growing fruits liable to the disease is practically impossible to obtain. However, concerted action on the part of all resident in a given district will be sufficient to so reduce the disease in that district that its presence will scarcely be noticed if it is not indeed entirely stamped out.

In the first place, let it be clearly understood that when once the disease enters a tree whether it be in fruit, twig, branch or trunk, there is no remedy for the affected part. The only measure to be adopted is to cut out and burn it right away. To cut off an infected twig will save the limb on which it grows; to cut out an affected large branch will save the trunk; and if the trunk be affected in only a limited area, the removal of the entire affected area will save the tree.

In cutting dead or diseased tissue from a tree, care must be taken to cut from six inches to a foot below the blighted area of a branch, and from two to four inches around a canker on a main limb or trunk. As previously pointed out, the germs are usually not confined to the visibly cankered area, but are penetrating within the bark in all directions for some distance beyond it. If only the visibly cankered area be removed the germs are still left in the tree, and the disease will continue to progress in the limb from which the cankered area was cut.

Some remarkable instances of such development came before our notice during the season. To quote one: Mr. Onslow, whose fruit farm is at Niagara-on-the-Lake, informed us, while visiting his farm on May 20th, that blight developed on most of his pear trees last fall. Every variety, one of which was the Kieffer, the most resistant variety, was affected. During the fall he cut out all the blight that he could find. Some of the trees were young and were so badly affected in the top that they were cut back right to the stump. Others that were more mature had limbs of various sizes removed.

Mr. Onslow is careful and thorough in his work, and he felt sure that he had cut out the disease entirely. However, when we examined the trees on May 20th, we found forty or fifty per cent. of them with the disease still progressing below the part cut. The disease had continued to spread below the cut area during the fall until the cold weather stopped it. When the warm weather of spring had started the sap again, the disease recommenced. The spring development of the

disease was readily distinguished from that of the previous fall. The latter showed the bark cankered, brown, dry, shrunken and separated from the former in many cases by a crack. The spring development of the disease showed the bark discoloured purplish to dark brown, somewhat swollen and somewhat moist in appearance. Mr. Onslow immediately cut these trees again eight inches to a foot below the visible affected part. Four of these pieces were brought to the laboratory, and we obtained pure cultures of the blight germ from every piece. When we again visited his farm in September no sign of the disease was found in any of these trees.

It is not advisable to do the regular pruning while cutting out blighted wood. There is the danger of carrying the germ on the tools used if they by any chance come in direct contact with the diseased part. Further, it is very desirable that the operator have with him a liquid disinfectant with which to swab the exposed cut surface, and also the tool used for cutting before it is used again on another limb. Formalin will do very well for such work, as it will not injure the steel tools. It may be carried in a bottle well corked, and a handy swab may be made by pushing a stout wire through the cork and wrapping a bit of cotton around the end that is to be inserted in the bottle.

The best time to cut out blight is the first time it is seen. Every case of active blight is a potent source of infection for innumerable other cases. However, it is not always practicable to locate every case of blight as it occurs. The best time for systematic action in an orchard is in late fall or early winter. At this time the diseased parts are more readily distinguished than in late winter or early spring, and if precautions be taken to burn the material cut out, this will insure the destruction of the beetles, aphids, and other insects harbouring on and in it.

We wish to lay special emphasis on the necessity for burning the diseased, dead, and cut away material in an orchard immediately after it has been cut. If dead trunks and large limbs of fruit trees are cut up for firewood they should be burned during the first winter. If they are allowed to remain until spring there is great danger of their sending out swarms of the fruit bark boring beetle which had wintered over in the wood in the grub stage. Mr. Caesar has recently traced several bad outbreaks of this borer in different cherry and peach orchards to such a source, and we infer from this that if they will do this with the cherry and peach they will do it with the pear. Figs. 41 and 42 show this inference to be warranted. The whole of the tree from which this branch was taken was riddled with such holes, and beneath the majority of these holes were larvæ of the beetle preparing to emerge in the spring as adults and make their way to other trees.

If an orchard be cleared of its blight during the winter as above indicated, there will be no germs there the following spring for insects to get contaminated with, and hence as the insects go from tree to tree they will not infect the blossoms. The blossoms not being inoculated, there will be no early twig blight, so that when the aphids come later in the season there will be no source of infection for them; and hence the

only damage they will do the trees which they visit will be to rob them of their sap which, as orchard men know, is bad enough, but is nothing compared with the blight. If, however, there are affected trees in the neighbourhood of the orchard, which is usually the case, then the only way to keep the disease out of the orchard is to control the insects.

Not much can be done with regard to controlling the bees. In some of the Western States there has almost been war between the fruit men and the honey men over this problem. It is not, however, the tame bee alone that is responsible for the dissemination of the disease among the blossoms, but the wild bees, wasps, ants, and other flower-visiting insects are equally guilty. Of course, spraying during blossom time would check this, but the law will not allow such measures because of the danger to the honey industry.

With the aphids, however, it is very different. They are lawful enemies at all times. Some fruit men contend that they are as great a pest as the codling worm, that is, when only their direct injury to the tree is taken account of; but when we add to this the damage they do by spreading the blight, their liabilities are increased a hundredfold. Hence the added necessity of keeping the aphids in check. Mr. Caesar recommends for their destruction spraying in spring, when the buds are just beginning to swell, with home-boiled lime-sulphur, preferably of the strength of twenty-five pounds lime, twenty pounds sulphur, to forty gallons of water. This is to kill the eggs which may be seen on the twigs and smaller branches of the tree. As it is seldom possible to destroy all the eggs by any wash, it will be wise to observe the buds as they are bursting and see whether any of the little green insects are present. If so, use kerosene emulsion of the ordinary strength for summer wash. To get good results, thorough work must be done. In the fall of the year observe if any aphids are present on the water-sprouts, where they will be found if they are on the trees at all at this time of the year. If present, cut off the water-sprouts and destroy them.

ORCHARDS INSPECTED.

1. Orchard of the Ontario Agricultural College, Guelph.

This orchard, though lying outside the recognized fruit growing sections, is capable of producing good crops of apples and pears of numerous varieties. It is used almost altogether for experimental work, variety tests, etc., and was kindly placed at our disposal by the Horticultural Department of the College for experimental purposes in connection with the blight.

The subjoined schedule, which was carefully filled in according to our directions by Mr. Cooper, orchard foreman, records full particulars of the number and varieties of trees in the orchard, all cases of blight which developed, and the nature of the attack, *i.e.*, whether inoculation occurred through blossom, twig, water-sprout, sucker, or body of the tree.

APPLE AND PEAR TREE BLIGHT SURVEY. O. A. C. ORCHARD, AUGUST, 1909.

Apple trees.	Total number of trees.	Number infected.	Percentage of blossom infection.	Percentage of twig infection.	Percentage of water-sprout infection.	Percentage of sucker infection.	Canker on main limbs or trunk.	Remarks.
Alexander	7	4	(1) 50 (1) 25 1 20	25	.....	25, 2 trees	on limbs 2 trees.	3 trees, very severe attack via bloom inoculation.
Behoni	2	1	.....	50	25	90	on limb.....	Developed between 1st and 31st August from bad aphis attack. Gummy exudate from cankers.
Brockville Beauty	1	1	.....	5	.....	.....	.....	
Canada Baldwin	3	2	.....	.....	10	.....	.....	Bad aphis attack on water sprouts.
Champion	1	1	.....	.....	3	.....	.....	
Colvert	5	4	70	5, 1 tree	10	10	limbs, 2 trees trunk, 1 tree....	This variety seems very liable to attack. Bloom inoculation very severe on all trees.
Coxe's Orange	1	1	.....	3	.....	.....	.....	Aphis attack on new growth.
Duchess	8	7	.....	3	20, 7 trees	.....	.....	Aphis attack on new growth.
Early Harvest	2	2	.....	.....	2, 1 tree	3, 1 tree	.....	Aphis attack on new growth.
Fallawater	5	3	.....	2	10	5	.....	Aphis attack on water-sprouts.
Fameuse	23	4	10, 1 tree	.....	20	5	.....	Aphis attack on water-sprouts.
Jones Fameuse	1	1	.....	.....	3	.....	.....	Aphis attack on water-sprouts.
Fall Jenetting	3	1	.....	2	.....	.....	.....	Aphis present.
Fall Pippin	3	1	.....	3	.....	.....	.....	Aphis present.
Fanny	3	1	1	1	.....	.....	.....	
Garden Gem	1	1	.....	4	.....	.....	.....	Aphis on new growth.
Gano	3	1	2	.....	.....	.....	.....	
Gideon	3	2	.....	.....	.....	3	.....	
Grimes Golden	3	1	3	.....	.....	.....	.....	
Hastings	3	2	.....	3	.....	.....	.....	Aphis on young growth.
Hubbardston	3	1	.....	.....	3	.....	.....	Aphis on young growth slight.

Hubbardston	3	1			5			Aphis on young growth slight

Hurlburt	3	3	10	5				Aphis on young growth.
King	3	2		2				
Longfield	2	1				5		Aphis on suckers.
McMahon	3	3	20	2		5		Severe bloom inoculation on 2 trees.
Maiden's Blush	2	1	2					
Milding	3	3	5	5	5			Aphis present on young growth.
Missouri Pippin	1	1		3				Aphis present on young growth.
Northwest Greening	3	1		1		20		
Northern Spy	12	5	5			25		On one tree all suckers attacked and diseases had penetrated to root.
Peter	3	3	3	1		5		
Pewaukee	3	2	2			3		
Red Astrachan	5	1			5			Aphis on water-sprouts.
Ribston Pippin	4	3	1	3		5	1 limb killed by canker.	
Romenskoe	1	1	20	20	50		limbs and trunk badly cankered	The worst affected in the orchard.
Rome Beauty	2	1	3					
Roxbury Russet	3	2	4	2			2 trees on limbs	1 tree, very bad attack of canker.
Russians 182 and 270.	2	2		12		10	limbs and trunk	1 tree dying, girdled by canker.
Salome	5	1				2		Aphis on suckers.
Scott's Winter	3	3		3	3			Aphis on young growth.
Seek-no-further	3	2		3		5		
Shackleford	3	3	1	3				
St. Lawrence	7	2	5	3				
Tolman Sweet	8	7	20, 1 tree 75	45	50	25	limbs, 3 trees	This variety most severely affected in orchard. Infection through bloom, twigs, suckers, and water sprouts generally heavy. Aphis attack bad.
Trenton	3	1				20		Aphis bad on suckers.
Vandevere	1	1		50				On this young tree planted in '07 the whole head was infected and had to be cut hard back during August to save it.
Wallbridge	6	3		15			2 trees, limbs; 1 tree, limbs and trunk	Very severe attack on young growth. Cankers on limbs and trunk at base of infected water-sprouts.

APPLE AND PEAR TREE BLIGHT SURVEY. O. A. C. ORCHARD, AUGUST, 1909. - *Continued.*

Apples and Pears.	Total number of trees.	Number infected.	Percentage of blossom infection.	Percentage of twig infection.	Percentage of water sprout infection.	Percentage of sucker infection.	Canker on main limbs or trunk.	Remarks.
Wagener	6	2				5		
Wealthy	7	2	4	3		5		Aphis attack.
Winter St. Lawrence	3	1				10		Bad aphis attack on suckers.
Yellow Bellflower	5	2				5		
Yellow Transparent	6	1		3				
CRABS.								
General Grant	3	2				25		Very bad aphis attack on suckers.
Hyslop	2	2		2		5		Very bad aphis attack on suckers.
Montreal Beauty	2	1				5		Very bad aphis attack on suckers.
Transcendent	3	3				5		Very bad aphis attack on suckers.
Whitney	2	2	5, 1 tree	2				
PEARS.								
Bartlett	4	1		10			limbs and trunk	Tree dying gradually.
Clapp's Favorite	8	2		3, 1 tree			limbs and trunk	1 tree 5 years old killed off; canker on trunk.
Dempsey	2	1	2				limbs	
Duchess	1	1		3				
Doyenne Boussock	2	1					trunk	
Easter Beurre	1	1					main limbs	
Flemish Beauty	24	11		3, 1 tree		5, 2 trees	limbs and trunk of 11 trees	1 tree 12 years old practically dead from canker on limbs and trunk.
Lawson	1	1					main limbs	
Lincoln	2	1					main limbs	
Petite Marguerite	1	1					limbs	
Ritson	2	2		2, 1 tree			limbs and trunk	1 main limb killed off.
Seckel	1	1					trunk	
Tyson	2	1	2				limbs	
Wilder	3	1					trunk	

APPLE AND PEAR TREE BLIGHT SURVEY, O.A.C. ORCHARD, AUGUST, 1909.

VARIETIES OF TREES NOT ATTACKED BY BLIGHT, WITH NUMBER OF TREES OF EACH VARIETY.

APPLES.

Babbit	2
Baldwin	2
Baxter	3
Belle de Boskop	3
Ben Davis	3
Bethel	3
Bietigheimer	2
Bienheim	3
Bottle Greening	3
Cinnamon	1
Cranberry	2
Delaware Red	3
Golden Russet	3
Gravenstein	5
Hare Pipka	2
Haas	3
Lady	2
Magog	3
McIntosh	3
McLean	3
Minkler	1
Northfield Beauty	1
Ontario	3
Peck's Pleasant	3
Primate	1
Rolfe	1
Shiawassie	3
Stark	3
Tetofsky	3
Utter	2
Wellington	2
Winter Banana	1
Wolfe River	3
Yellow Imperial	1

CRABS.

Martha	3

PEARS.

Anjou	16
Bartlett Seckel	1
Belle Lucrative	2
Beurre Hardy	2
Bessemianka	3
Bosc	1
Dr. Jules Guyot	1
Gifford	2
Goodale	2
Howell	2
Josephine de Malines	2
Kieffer	1
Lawrence	3
Louis Bonne	3
Manning's Elizabeth	3
Novo Fulvie	1
President Drouard	1
Sheldon	3
Vermont Beauty	1

The schedule shows the large number of varieties that are liable to infection. Even those varieties that showed no development of the disease are not necessarily exempt from its attack, but for some reason or other not known they have not so far shown signs of the disease. The diseased trees were scattered all over the orchard, so that all trees were equally liable to attack.

The varieties of apple in which the disease spread most rapidly when once it gained entrance are: First, Tolman Sweet; second, Romenskoe and the Russians Nos. 182 and 270, and third, the Colvert. In all these, especially the Romenskoe, large and very bad cankers developed in the bark of the trunk and main limbs at the base of water sprouts that were infected. Around some old cankers the bacillus had lived over winter and became active again in the spring. This appears to be rather a rare occurrence in other varieties. (See Figs. 23, 36, 37.)

Note that the disease in the apple trees is nearly all in the young growth, while in the pear trees it is confined largely to the main limbs and trunk.

Among the pear trees there was practically no spread of the disease from tree to tree. But the disease spread rapidly in those trees in which it had wintered over. All cases of new infection were those of our own inoculation experiments.

The Flemish Beauty, Clapp's Favourite and Bartlett were the varieties in which the disease spread most rapidly.

The schedule was filled in during August. During September and October no new cases were observed, but all cases of infection continued

to spread, and numerous cankers developed at the base of water-sprouts that had been inoculated by aphids.

2. Mr. Dudley's Apple Orchard, Whitby, June, 1909.

This orchard contains about five hundred and fifty mature apple trees of eleven varieties. Mr. Dudley purchased it four years ago from its former owner, who had not found it a paying proposition. By cultivation, manuring and spraying, Mr. Dudley has obtained good returns. This year, however, after the blossoming season he noticed much of the young growth withering. At first he thought he had sprayed too heavily, but later, on finding that the withered twigs increased in number and size, he applied to Mr. Hare, District Representative of Agriculture, for information on the subject, and thence the matter came before our notice. We made an inspection of the orchard, and found it to be suffering from a very bad attack of twig blight, due to blossom infection.

The following schedule gives particulars:

Variety.	Number of Trees.	Number of trees attacked	Percentage of twigs infected.	Remarks.
Tolman Sweet..	15	15 (100%)	80–90	All trees badly affected. Russets, Kings, Baldwins, Ontarios, all round lightly affected.
Baldwin..	192	56 (29.1%)	20–30	
Greening	125	115 (92%)	20–50	
Spy	35	9 (25.7%)	5–20	
Spy grafts.....	40	.....	.....	No fruit on trees. Healthy foliage.
Duchess	24	15 (62.4%)	20–70	One very badly affected Those not much diseased held but little fruit.
King	18	4 (22.2%)	10-20	Not much fruit.
Ben Davis	10	.....	.....	An odd twig here and there infected, very little fruit.
Snow	10	.....	.....	An odd twig here and there infected, very little fruit.
Russet	31	8 (25.5%)	5–15	
Ontario.....	42	16 (38%)	10–20	Fair amount of fruit.

It will be seen from the above schedule that the Tolman Sweet variety was the worst attacked. The trees had blossomed heavily, and nearly every blossom on every tree had been destroyed by the blight, which passed into the twigs, killing them as it progressed. The Greenings came second in severity of attack and rapidity of spread, and the Baldwins third. It will be noticed that the trees not blighted had not blossomed.

3. An apple and pear orchard belonging to Mr. Bunker, of Pickering, proved, on examination, a splendid object lesson of what may

be done by the employment of proper means in combating disease in trees. This was an orchard of mature trees, and when purchased two years ago was suffering badly from blight canker and New York Apple Tree Canker on the main limbs and trunk of the trees. Early this spring, upon the advice and with the help of Mr. Hare, District Representative of Agriculture, who superintended the operations, all cankers

Fig. 45. Clapp's Favorite pear tree used in Experiment 5. The two twigs to the extreme right were the twigs inoculated. The disease passed down them to the crotch, from which it spread to all the other limbs and down the trunk.

were radically removed, and all blighted limbs and twigs were cut away, and three successive coats of thick white lead were given to the exposed areas. When we visited the orchard in June, it was in a state of thorough cultivation, every tree looked clean, healthy and vigorous, and not a sign of blight could be found. The owner stated that he kept

a sharp eye on the trees, and whenever he observed a case of blight he at once cut it out. We found numerous cases of blight in the neighbourhood of the orchard on apple, pear and hawthorn trees, so that it was simply due to the precautions taken that no blight was within the orchard. The owner's vigilance was amply rewarded.

4. Many of the pear trees in the orchard of Mr. Bartlett, Whitby, were badly blighted in the trunk and main limbs. When the

Fig. 46. Detail of same tree represented in Fig. 45, showing the blistered, cankered area outlined by the cracks in the bark down the trunk and up the limbs.

orchard was visited in June the disease was very active, and spreading rapidly within the trees affected. A few new infections from blossom inoculation were noticed. This orchard was under cultivation.

5. The pear orchard of Mr. Huggard, Whitby, was in sod, in which condition it had been for two years. Several trees killed by blight the

previous season were still standing, and numerous other trees had the disease, but not in a very active condition. The old cankered areas were plentiful in the trees, but the current season's development around these cankers was comparatively slight. A young apple orchard belonging to the same owner had considerable twig blight, due to blossom infection; in these cases the disease was very active.

Fig. 47. Flemish Beauty pear tree used in Experiment 5. The tip of the twig in centre was inoculated. The disease killed it and passed into the branch at its base. This it girdled, which resulted in the death of the branch.

6. In the orchard of Mr. Bunting, St. Catharines, we found an isolated row of pear trees, Flemish Beauty and Bartlett, that were very badly blighted in the trunk and main limbs. Two of them were dead, and the rest were so near it that Mr. Bunting had already decided to remove them. This row had formed a part of a pear orchard, all the

other trees of which had been killed by blight and removed from time to time.

7. Mr. W. McCalla, of St. Catharines, has a pear orchard containing Kieffer, Clapp's Favourite, Bartlett, Clairgeau, and some other varieties. He had cut out all the blight he could find last fall, but we found it to be still present and active on many of the trees, including the Kieffers. The orchard was under cultivation.

Fig. 48. Young apple tree used in Experiment 5. The branch in the centre is the one inoculated. The whole branch was killed. Note that the few leaves remaining on this branch are dead and shrivelled.

8. Mr. Stagg, St. Catharines, three years ago had a mature pear orchard of about two hundred trees. This season he had about thirteen of these left, all the rest having been removed after dying from the blight. The thirteen that remained were all badly blighted, and when

we were looking them over in July the disease was very active, the bark on the main limbs and trunk was blistering, and much thin, gummy liquid was exuding from the freshly cankered parts. Mr. Stagg intended to tear them all out this fall.

9. Mr. T. D. Jarvis, Grimsby, has three pear orchards, all in sod. One of these is composed of twelve-year-old Kieffers. Almost every tree in this orchard bore evidence of an attack by blight about three years ago. The ends of many branches had been killed back to a distance of from six to thirty inches, and in many cases the disease had continued to pass down the under side of the branch until a main limb or the trunk was reached; here usually it stopped, and there was but very little evidence of blight on the main limbs and trunk. The dead bark had shelled from many of these cankers, which had run down the under side of the branches, and the living bark was gradually healing over the wound.

The other two orchards contained several varieties of pears, Flemish Beauty, Clapp's Favourite, Bartlett, and others. These had a considerable amount of old blight canker in them, but not much that was very active, due probably to the fact that they had been in sod two or three years.

Mr. Jarvis has also a mature Greening apple orchard, and a mature Baldwin apple orchard. Both of these were badly infected with twig blight, due to blossom inoculation by bees and other flower-visiting insects, and later to the spread among the water-sprouts and young twigs by aphids. Nearly all the young growth on some trees was killed back by the blight.

Other orchards that we visited were those of Mr. E. D. Smith, of Winona, Mr. Tweddle, of Fruitlands, and Mr. Onslow, of Niagara-on-the-Lake, all of which we have referred to in the text.

In addition to these, we called in numerous other orchards while passing through the various districts visited. In these we found conditions similar to those already described. Wherever we went we could not fail to be impressed by the extensive ravages and heavy losses caused by the blight in the pear and apple orchards throughout the fruit districts generally.

We are thoroughly convinced, however, that with concerted action on the part of the fruit-growers, due care and adequate precautions as we have already suggested, the disease may be brought well under control, if not entirely eradicated, from our midst.

EXPERIMENTS.

EXPERIMENT 1.—April 17th. (*a*) Inoculated two twigs on each of three Bartlett and three Flemish Beauty pear trees with broth cultures six days old from laboratory stock cultures of *B. amylovorus*. Inoculations were made by first puncturing or slightly tearing the bark near the end of the twig with a steel needle sterilized in an alcohol flame, then

with a sterile camel's-hair brush dipped into the broth culture, filling up the wound.

(*b*) Incisions made into bark of the main limbs of the same trees

Fig. 49. Blight cankered limb of Bartlett pear tree used in Experiment 2. The lower limit of the canker is shown by the irregular crack in the bark. The tissue used for culture experiments was taken from two inches within (*a*) and two inches without (*b*) the cankered area.

Fig. 50. Agar plate culture of *B. amylovorus*, obtained from the maceration of inner bark tissue taken from (*b*) outside the canker shown in Fig. 49. Every white dot is a colony of bacteria. The culture was pure. Incubated at 25° C. (Natural size.)

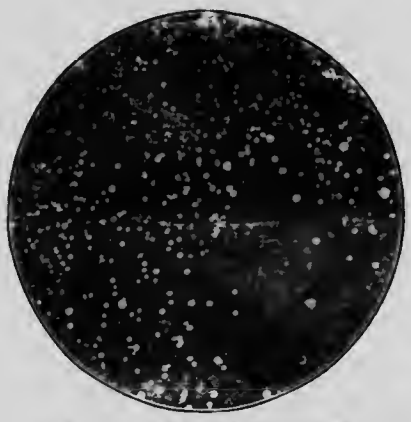

Fig. 51. Agar plate culture of *B. amylovorus* from a dilution of the mulch used for plate shown in Fig. 50. Incubated six days at 25° C. (Natural size.)

used in experiment (*a*). These wounds soaked with the broth culture by means of the camel's-hair brush.

(*c*) Two twigs on each of six young apple trees treated in the same way as the pear twigs in experiment (*a*).

(*d*) Main limbs of the apple trees used in experiment (*c*) treated in same way as the limbs of pears in experiment (*b*).

Result.—Not one of these inoculations resulted in a development of the disease.

EXPERIMENT 2.—April 17th. Cut a cankered limb (see fig. 49) from a Bartlett pear tree. Washed the exterior with $HgCl_2$, 1-1000, and with sterile knife obtained small portions of the inner bark from the cankered area and also from the discoloured area two inches from the crack marking the limits of the canker. This tissue was macerated in small quantities of sterile water, and three plate cultures of varying dilutions were made from each in beef-extract agar and gelatin; agar plates incubated at 25 deg. C. and the gelatin plates at 20 deg. C.

In twenty-four hours numerous minute colonies were seen on the agar plates made from the tissue taken from outside the cankered area, and in forty-eight hours similar colonies appeared in the gelatin plates made from the same material.

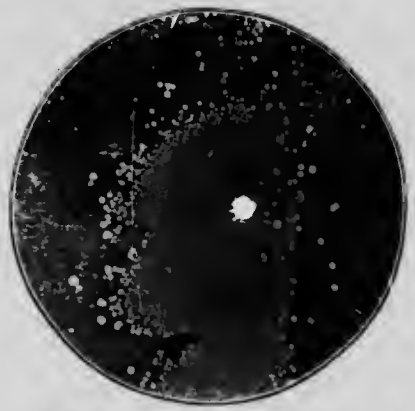

Fig. 52. Agar plate culture of *B. amylovorus* from inner bark of blighted apple twig. (Natural size.)

These all subsequently proved to be pure cultures of *B. amylovorus*. (Fig. 50.)

No colonies of *B. amylovorus* were obtained from the tissue taken from the cankered area. This tissue was dark brown, dry, tough, and evidently dead, while the tissue taken from outside the cankered area was moist and living, although it also was discoloured brown.

These experiments were subsequently duplicated after the limb had remained drying in the laboratory for six weeks, and similar results were obtained.

Conclusions.—The blight organisms live over winter, not in the dead cankered tissue, but in the living bark immediately surrounding the cankered area. This bark is usually discoloured purplish or dark brown. Many such cases were observed.

EXPERIMENT 3.—April 18th. Drew a pruning saw through the diseased bark of a Bartlett pear tree, and then with the saw made incisions into the bark of three pear trees and three apple trees, also cut off small branches from the same trees.

Result.—By the end of May, four of these cases developed the disease.

Conclusions.—When pruning, one should take care to cut well below cankered areas, and after cutting out a diseased limb should disinfect the cutting instrument.

EXPERIMENT 4.—May 6th. Isolated pure cultures of *B. amylovorus* in beef-extract agar, and gelatin from:

(*a*) Cankered pear limbs brought from the orchards of Mr. Onslow, Niagara-on-the-Lake.

June 10th. (*b*) Apple twigs from O. A. C. orchard.

(*c*) Young apple fruit, O. A. C. orchard.

(*d*) Exudate on diseased Bartlett pear, O. A. C.

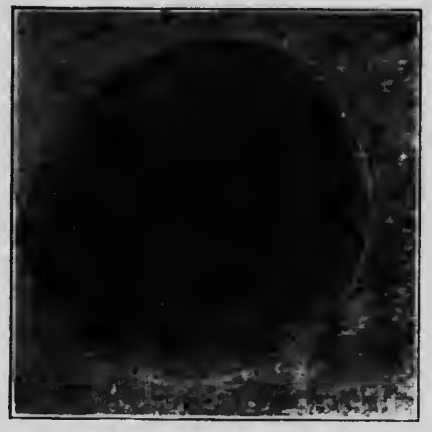

Fig. 53. Surface colony of *B. amylovorus* from agar plate culture shown in Fig. 51. Magnified 50 dia.

EXPERIMENT 5.—June 16th. (*a*) Inoculated one twig on each of twelve young healthy pear trees and on each of twelve young healthy apple trees with agar culture of *B. amylovorus* obtained from diseased pear tree limbs, Exp. 4 (*a*).

(*b*) Duplicated the above on the same trees with agar culture of *B. amylovorus* obtained from diseased apple tree twigs, Exp. 4 (*b*).

These inoculations were made by puncturing and slightly tearing the bark at the tip of the twig with a steel needle sterilized in an alcohol flame. The needle was then resterilized, and with it a small portion of the culture from the surface of the agar was transferred to the puncture.

In three days all twigs inoculated showed signs of the disease. The bark in the immediate neighbourhood of the puncture was brown and watery-looking. The young, unfolding, terminal bud leaves near the puncture were tinged a light reddish brown colour.

In three weeks the disease had visibly spread down some of the pear twigs from five to eight inches, and globules of amber-coloured gummy exudate were a marked feature on some of these. The disease progressed more slowly in the apple twigs. The leaves at the end of the twigs were light brown on the apple and dark brown or black on the pear, were gradually shrivelling, and the ends of the twigs were drooping as if dead.

By the end of August, in the case of a Clapp's Favourite pear, the disease had passed down the two twigs inoculated to the main branch which bore them, down this main branch to the crotch of the tree, a

Fig. 54. Submerged colonies of *B. amylovorus* from plate shown in Fig. 51. Magnified 50 dia.

distance of four feet from the point of inoculation; at the crotch it entered the three other main limbs, up each of which it had progressed more than a foot, and also eight inches down the trunk. The bark of all these affected parts was cankered, cracked, and discoloured dark brown, and the characteristic gummy exudate was plentiful at various points. The leaves on the branch down which the disease had passed were black, shrivelled and dead, and the leaves all over the rest of the tree were beginning to look sickly, *i.e.*, turning dark brown, owing to the disease rapidly cankering the main limbs and trunk. By the end of the season the whole tree top and half of the trunk will be dead. (See Figs. 45. 46.)

This experiment shows the great rapidity with which the disease will spread when once it gains entrance to a susceptible pear tree. (See also Fig. 47.)

In none of the inoculated apple trees did the disease spread so rapidly as it did in any one of the pear trees. The apple tree which showed the greatest development was a Tolman Sweet. In this case, by the end of September the disease had passed a distance of three feet four inches down the twig and branch, killing the whole of the branch, but not seriously affecting the rest of the tree. (See Fig. 48.)

EXPERIMENT 6.—June. Obtained a blighted fruit spur from Yellow Transparent apple tree, O. A. C. orchard, in which the disease was active. Three blossoms had been killed, the disease passing down their pedicels to the spur, and then up two other pedicels, the fruit on which had developed to three-quarters of an inch in diameter when it became diseased. Diseased part of fruit brown, slimy, somewhat viscid when cut, surcharged with blight organisms. Cultures were made from

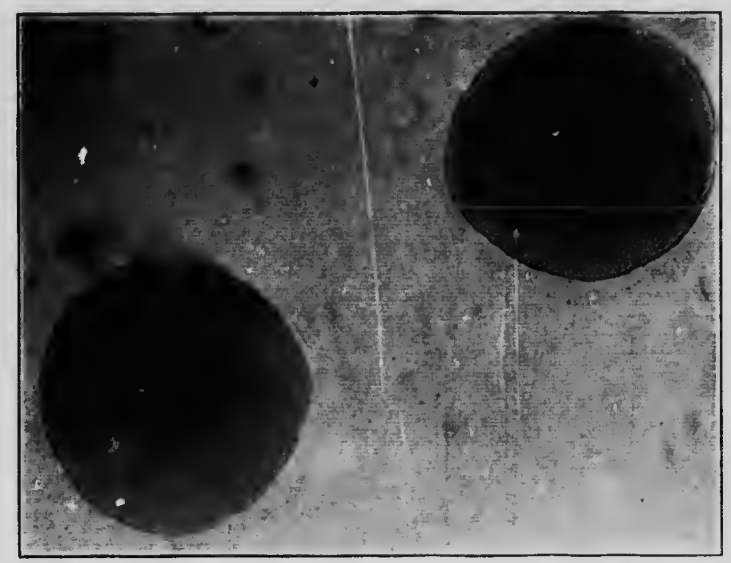

Fig. 55. Surface colonies of *B. amylovorus* on gelatin. Incubated three weeks at 20° C. Magnified 50 dia.

the fruit. The diseased tissue and pedicels were embedded in paraffin, and from each sample four-micron sections made, and stained with carbol fuchsin. These sections showed dense masses of organisms within the plant cells. In some cases some of the cell walls were broken down, in other cases numerous individual organisms were to be seen within the cells whose walls were not yet destroyed. (See Figs. 11, 12. 13, 14.)

EXPERIMENT 7.—June. Obtained fruit bark boring beetles, *Scolytus rugulosus,* in sterile test tubes from bark of diseased pear tree in O. A. C. orchard. Allowed one beetle to walk over surface of each of three

plates of beef extract agar and three plates of beef extract gelatin. In two days numerous colonies of *B. amylovorus* developed in their tracks. (See Fig. 39.)

EXPERIMENT 8.—July 4th. Obtained blighted twigs of apple trees, O. A. C. orchard, that were infested with aphids. Made cultures in beef agar and beef gelatin from the inner bark of the twigs and from the aphids. The heads of the aphids were macerated in a drop of sterile water and dilutions of this mixture were used in the plates. Pure cultures of *B. amylovorus* were obtained from the bark tissue, and mixed bacterial cultures obtained from the aphids. Many of these latter colonies were *B. amylovorus*.

EXPERIMENT 9.—July 6th. Obtained flies, *Musca domestica*, from surface of gummy exudate on diseased limb of pear tree on which the flies were feeding. Flies allowed to walk over beef agar plates. Numerous colonies of *B. amylovorus* developed in their tracks in two days.

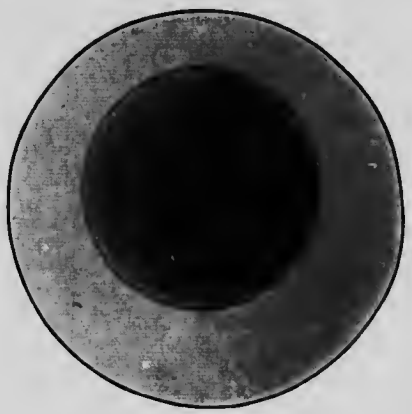

Fig. 56. Surface colony of *B. amylovorus* on gelatin. Incubated three weeks at 20° C. Magnified 50 dia.

EXPERIMENT 10.—July 10th. Brought six healthy young twigs of Flemish Beauty pear and six healthy young twigs of Yellow Transparent apple to the laboratory. Stood them with cut ends in flasks of tap water.

(*a*) Inoculated three of the apple twigs and three of the pear twigs with pure cultures of *B. amylovorus* grown on agar, by puncturing the bark at the tip of each twig with a sterile needle and transferring a little of the culture directly to puncture with the needle.

(*b*) Smeared on the outside of the bark of the other three apple twigs and pear twigs some of the culture.

Result.—In three days each of the three apple twigs in (*a*) showed signs of the disease. The terminal bud leaves were browned and the bark at the end of the twig also showed the organisms in numbers. The

pear twigs did not show such marked signs of the disease, but a blackening of the bark around the puncture was produced. No signs of the disease developed in (*b*) at any time.

EXPERIMENT 11.—July 10th. Obtained nine young apples and nine young pears.

(*a*) Inoculated by puncture two apples and two pears with pure culture of *B. amylovorus* grown on agar.

(*b*) Inoculated two apples and two pears by puncture with gummy exudate from diseased apple taken from a blighted tree.

(*c*) Smeared agar culture of *B. amylovorus* over surface of two apples and two pears.

(*d*) Smeared exudate from diseased apple over surface of two pears.

Fig. 57. Submerged colony of *B. amylovorus* in gelatin. Incubated three weeks at 20° C. Magnified 50 diameters.

Kept one apple and one pear as controls.

These fruits were placed in sterile deep Petri dishes, to which a little sterile water was added, and incubated at 25°C.

In three days the tissue around all the punctured inoculations was softened and turning brown. In three weeks the skin over about one-third of the surface of each of these was wrinkled, somewhat sunken, dark brown, the tissue beneath soft, pulpy, slimy, and teeming with the organisms. In several instances drops of amber-coloured exudate were on the surface.

None of the fruits on which the culture or exudate were smeared developed the disease.

The controls remained sound. (See Figs. 15 and 16.)

BACILLUS AMYLOVORUS.

Morphology and Cultural Characters.

Source.—Two cultures were isolated, one from a diseased apple twig and one from exudate on a diseased pear tree, O. A. C. orchard, June 10th. These cultures were used to inoculate young pear and apple trees in Exp. 5. The two strains were again isolated from the inoculated trees in which the disease had rapidly spread and were carried simultaneously through the various culture media with like results.

I. Morphology.

Veg. cells from diseased tissue, agar colonies 3 days at 25°C., gel. colonies 5 days at 20°C., and bouillon cultures 3 days at 25°C., short rods, rounded ends; mostly single, sometimes in twos. Chains of from 4 to 12 segments are a characteristic on Loeffler's blood serum. Limits of size, 1 to 1.8 x .5 to .9 microns.

Fig. 58. Group of small surface colonies on gelatin. Incubated three weeks at 20° C. Magnified 50 dia.

Spores.—None observed at any time in any medium.

Flagella.—1 to 3 at or near one pole. Stained by Moore's modification of Loeffler's flagella stain. Figs. 3, 4.

Staining Reactions.—Watery and alcoholic solutions of gentian violet, carbol fuchsin, and methylene blue, good; Gram's, negative; Ziehl-Neelson, negative.

II. Cultural Features.

Agar Stroke.—Growth moderate, filiform, slightly raised, glistening, young cultures smooth, older cultures tendency to contour, slightly gray, semi-opaque, butyrous.

Potato.— Growth moderate, slowly spreading, flat or slightly raised, glistening, smooth, colourless, butyrous.

Loeffler's Blood Serum.—Colourless growth similar to that on agar, no liquefaction.

Agar Stab.—Filiform, uniform growth.

Gelatin Stab.—Filiform, uniform growth; slight tendency to liquefaction on surface after 20 days.

Nutrient Broth.—Moderate clouding, uniform; no pellicle; no ring; scant, finely graular sediment after 10 days at 25°C. No odour.

Milk.—Soft coagulum after 4 days at 25°C. Very slight digestion after 20 days at 25°C.

Litmus Milk.—Turned white in 4 days, slightly pink in 6 days, white again in 12 days, upper layers blue again in 18 days.

Gelatin Colonies.—Growth rather slow, round, slightly raised, entire, gray; young cultures finely granular, older ones grumose when seen through microscope low power; no liquefaction after fifteen days. (Figs. 56, 57, 58.)

Agar Colonies.—Growth rapid at the start at 25°C., but maximum development obtained in 5 or 6 days; usually small, not more than 2 to 3 millimetres; round, smooth, flat or slightly raised, entire or undulate, young cultures finely granular, older ones coarsely granular to grumose. (Figs. 53, 54.)

Silicate Jelly (Fermi's solution).—Moderate growth on surface, thin, grayish; medium not stained.

Starch Jelly.—Growth moderate, diastasic action present on third day at 25°C., the upper layers being liquefied; after 6 days 30 per cent

Cohn's Solution.—No growth. NOTE.—This medium tested +43° to phenolphthalein, Fuller's scale. A portion was reduced to +10° by addition of NaOH. This caused a precipitate of magnesium hydroxide, which was filtered out. No growth occurred in this solution.

Uschinsky's Solution.—Growth copious, not . cid.

Sodium Chloride in Bouillon.—½%, 1%, 1½%, 2%, 2½%, 3% of sodium chloride added to bouillon medi . 3° acid did not inhibit growth at 25° C. The higher percentages of salt checked the growth on first 2 days, but after 4 days all media were densely clouded and had a granular precipitate.

Nitrates in Nitrate Broth.—None reduced; no ammonia, no nitrates, no free nitrogen produced.

Indol.—None fo med in Dunham's solution.

Toleration of Acids.—Bouillon 4° acid to phenolphthalein used as foundati stock. To this was added HCl, increasing acidity to +8°, +10°, +12°, +14°, +16°. In 2 days at 25° C. uniform clouding in +8° and +10°; no perceptible growth in +12°, +14°, +16°. In 4 days

uniform clouding in each tube, but the density of growth decreased as the acidity increased.

Toleration of NaOH.—Same foundation stock used as for the acid test. NaOH added to increase alkalinity to -2°, -4°, -6°, -8°, -10°. Growth occurred in media up to -6°.

Optimum Reaction.—Neutral.

Vitality on Culture Media.—Seldom living in any medium after 5 months in the dark at room temperature.

Temperature Relations.—Freshly inoculated bouillon cultures exposed 10 min. at 50° C. were killed.

Similar cultures exposed 10 min. at 45° C. were not killed.

Bouillon cultures incubated at 37° C. did not develop.

Bouillon cultures placed in refrigerator showed no development in 5 days.

Agar plates freshly seeded were placed in ice and salt freezing mixture, temperature of which varied from 0° C. to -10° C. Two plates were removed after each of the following periods of time, and incubated at 25° C.—30 min., 1 hr., 2 hrs., 4 hrs., 8 hrs., 20 hrs. Growth occurred in every case. 50% killed in the 20 hrs., freezing. Best temperature for growth, 23° C. to 25° C.

Resistance to Drying.—Cover glass smears of broth cultures dried in the dark, at room temperature, for 5 days, gave good growth in bouillon.

Similar smears dried in bright sunlight for 30 minutes gave growth in bouillon.

Similar smears exposed to bright sunlight 30 minutes and kept dry in laboratory for 6 days gave no growth in bouillon.

Sunlight.—Thinly sown agar plates exposed to bright sunlight for 15 minutes showed after incubation about 5 per cent. killed. Similar plates exposed under same conditions for 30 minutes showed about 15 per cent. killed.

Fermentation tubes containing peptone water and:

2% Dextrose gave no gas, but a strong, clouded growth throughout.

2% Saccharose gave no gas, but a light, clouded growth throughout.

2% Lactose gave no gas, but a light, clouded growth throughout.

2% Maltose gave no gas, but a strong, clouded growth throughout.

2% Glycerin gave no gas, but a light, clouded growth throughout.

2% Mannit gave no gas, but a strong, clouded growth throughout.

A very slight increase of acidity resulted from growth after 5 days.

Pathogenesis.—Pathogenic to following genera of Rosaceæ: Pyrus, Cratægus and Amelanchier.

SUMMARY OF CONCLUSIONS.

1. Bacterial blight of apple, pear and quince trees causes more loss to the pome fruit grower in Ontario than any other agent of loss.

2. *B. amylovorus*, the cause of the disease, lives in the cells of the bark and fruit, the contents of which it destroys, causing withering of the twigs, canker of the limbs and trunk, and rot of the fruit.

3. The disease is spread from branch to branch, from tree to tree, and from district to district—(A) by insects carrying the germ on the outside of their bodies, (1) bees, wasps and other flower visiting insects inoculating the blossom, (2) aphids and other sap sucking insects inoculating twigs; (3) fruit bark boring beetles and other borers inoculating branches and trunks; (4) saws, knives and other workmen's tools when pruning operations are in progress.

4. All blighted parts of trees should be cut away as soon as noticed where possible. Systematic cutting out of blighted parts should be practised during late [illegible]. When cutting away an affected part, care should be taken to cut well below or around the blighted area. The instrument used should be disinfected each time after use. Care should be taken not to rub a diseased part against a healthy part when removing it. All diseased wood should be burned as soon as cut away.

5. Aphids and borers, active carriers of the disease, should be kept in check.

Seeing that this year the Government appointed a number of orchard survey men to report on the conditions found in the orchards throughout the Province, we would strongly recommend that for their work next season these surveyors be trained to recognize the blight in its various forms of attack, twig and canker on the apple, pear and quince trees, and be able to give the necessary advice to those immediately concerned as to the proper methods to be adopted in its control and eradication.

In conclusion, we wish to thank, for kind assistance given from time to time during this investigation, Prof. S. F. Edwards of this department, Dr. Bethune, Messrs. Jarvis and Caesar of the Biological department, and Mr. Cooper, the orchard foreman at the College. We wish to thank also all the farmers whose orchards we visited, who were only too willing to answer all questions and to show us around their orchards, even during the busy season when they could ill afford the time necessary.

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