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Bitter-pit of the Apple.

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BITTER-PIT OF THE APPLE.

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Introduction.

In February, 1906, my attention was drawn by Mr. C. P. Lounsbury, the Government Entomologist, Cape Colony, to a peculiar spotting in Cape apples. The trouble was known locally simply by the name of "bitter-pit," and as it is now so commonly recognised under this name I do not propose in this report to substitute any other, although there are certain objections to the term here employed.

In the following month, Mr. Lounsbury conducted me over the orchards of the Cape Orchard Company at Hex River, where the spotting was very evident both on the fruit on the trees and also on the apples which were in cold storage.

The prevalent theory in vogue regarding the trouble at the time was that it was due to a mechanical injury brought about by blown sand. A number of varieties of affected apples were then collected for microscopic examination, and as the disease was one of such general importance, arrangements were made with the Cape Department of Agriculture that I should devote as much time as I could spare to an investigation of this trouble. The Cape Orchard Company also very kindly undertook to place the necessary facilities, in the shape of conducting experiments at their orchards, at my disposal.

An exhaustive histological and bacteriological examination of these spots was first carried out, but neither revealed any evidence of fungi or bacteria. In the histological part of the enquiry, however, a great abundance of starch in the diseased areas at once suggested that the action of diastase must be inhibited in some way or other, and that possibly some chemical constituent might be lacking which was necessary for the complete conversion of the starch into sugar. At this stage, Mr. Herbert Ingle, late Chief Chemist to this Department, became much interested in the problem, and kindly offered to assist me in the investigation by making analyses of soil, healthy and diseased apples, etc.

It was then arranged that we should publish a joint report on this subject, but, unfortunately, owing to unforeseen circumstances, Mr. Ingle left South Africa before he was in a position to publish his results, and it has therefore been deemed advisable in the interests of the fruit-growing community to delay no longer the present conclusions, which are merely put forward with a view to suggesting certain lines upon which apple growers in this country should work in order to minimise their losses through this trouble.

It has not been possible to carry these investigations as far as might have been done. This is owing to the great distance of suitable orchards for conducting the experiments from my headquarters, and it is chiefly on this account and pressure of other work that compels me to abandon a further prosecution of this subject under existing circumstances; for when it is stated that the majority of the experiments and observations have been carried out at a distance close on a thousand miles from the laboratory, some of the difficulties involved will be fully realised.

Before I proceed to an account of the trouble, it will be well to briefly refer to the more important literature already published on this subject from other parts of the world, and to note the observations and conclusions there arrived at.

Literature.

In 1891 *Jones* (1) described the general appearance of the disease, but on the authority of J. B. Ellis put it down to the fungus *Dothidea pomigena*, Schw. Jones says that it is quite common upon Baldwin apples throughout the Vermont State, but that its occurrence upon other varieties was not noticed.

Cobb (2) a year later describes the disease, which he says causes considerable loss. He was at first inclined to believe that it was due to the insect *Dindymus versicolor*, but, after a careful examination, was unable to trace any insect puncture, and concludes that the cause is unknown.

Wortmann (3) in 1892 reports the trouble in Europe, and names a number of varieties of apples on which the spot occurs. Large sappy varieties are especially liable to spot, according to Wortmann. He concludes that the death of the cells is due to a concentration of sap following loss of water by direct transpiration in the case of the superficial cells, or by excessive conduction of water to the transpiring surface layers in the case of the deeper seated cells.

Lamson (4) in 1897 says that the Baldwin apple in Southern New Hampshire has been badly affected with the spot for the last three years, and thinks that it is of fungous origin. He conducted experiments during the seasons of 1895 and 1896 on Baldwin apples with "Bordeaux mixture" and from the experiments of both seasons it is quite evident that the spraying was advantageous.

Zschokke (5) in 1897 confirmed and extended the work of Wortmann. He paid particular attention to the epidermis and its relation to the keeping qualities of the fruit. Zschokke considered that the relative rate of water conduction was the most important factor in determining the susceptibility of apples to the spot disease.

Jones and *Orton* (6) in 1897 mention that although the spot trouble was worse in Baldwins, it is also common in Northern Spies and Greenings. They remark that the spots were more numerous at the apical end, and that they were not confined to the surface, but in some cases were deeply seated. They note that the spots were associated with the vascular bundles, and occurred at or near the veins. They advance no suggestion as to the cause of the disease, but simply say that they failed to associate fungi or bacteria with the spots.

Lamson (7) in 1899 gives the results of his spraying experiments for the Baldwin fruit spot. He sprayed the trees three times with one to ten "Bordeaux mixture," once before blossoming, again just after the petals had fallen, and again two weeks later. He found that the unsprayed Baldwins showed 48 per cent. free from spots, while the sprayed trees showed 78 per cent. free from spots.

Stewart (8) describes the external appearance of the disease in Baldwin apples, and says that Wortmann thinks it due primarily to insufficient water in the affected parts. He notes the fact that the stem half of the apple remains free, while in the calyx half the spots were not only confined to the surface but extended into the middle of the tissue at the calyx end, especially if the apples were kept for some little time in the laboratory. His experiments with apples kept in moist chambers showed that although the spots did not increase in number externally, internally within the fruit they did increase in number. Trials to produce any growth in culture media entirely failed. Stewart says that Wortmann observed that starch was present, often in abundance, in the brown spongy tissue, while the surrounding healthy tissue was destitute of starch. Stewart found that the starch is far more abundant in the spots near the epidermis than those more deeply seated. Stewart comes to the conclusion that the real cause is unknown.

Macoun (9) in 1899 says that the disease has been under investigation for some years, and that during the years 1897–98 nineteen varieties of apples were affected at the experimental farm, some being so badly injured that the fruit was almost worthless. Spraying with fungicides appeared to have no effect in reducing the disease. From enquiries which he made, he learnt that at least sixty varieties of apples in Canada and the States were affected, and that the Baldwin apple suffered most of all. while the disease had been observed for twenty-eight years.

Maynard (10) in 1900 reports that the spotting has so injured many varieties of apples for the last three or four years as to render the fruit almost unmarketable. From experiments carried out at the station and other localities with fertilizers and various methods of cultivation, it is concluded that the disease is due to premature and imperfect ripening. Light soils exposed to the south, and containing large supplies of nitrogen, are said to favour the spotting, while in cool soils well supplied with potash and with a northern aspect, little or no spotting is found.

McAlpine (11) in 1902 notes the fact that bitter pit has been very prevalent for the last few years in Australia, and that some of their most valuable apples, such as Jonathan, Cleopatra, Scarlet Nonpareil, and Esopus Spitzenberg have been particularly subject to it. He advises shippers to exercise great care in selecting their apples for the London market, as numerous complaints have been received from London regarding the disease in Australian and Tasmanian apples.

Quinn (12) in 1905 gave an account of his observations on the disease in South Australia. He thinks that there is but little doubt that the combined presence of much moisture and high temperatures appear to be predisposing in their influences. A list of the varieties of apples commonly grown in South Australia is given, showing their comparative immunity to the spot. Quinn's experience is, that wherever vigorous growth

occurs, and abundance of moisture is supplied, there the spotting is very prevalent. One very important suggestion made by Quinn is that of the possible influence exerted by the stock in the scion, for he points out that nearly all Australian apple trees are grafted on Northern Spy stocks in order to resist the attacks of the American blight or woolly aphis, and it is well known that " the fruits of the Northern Spy are notoriously affected by the ' bitter-pit.' " In support of this, Quinn brings forward the comparative immunity of Tasmanian apples to bitter-pit, which he thinks may be due to the fact that they are on their seedling stocks, or that the vitality of these stocks may be so impaired by the suctorial action of the woolly aphis.

Massee (13) in 1906 describes the disease as found in a sample of Cape apples sent to Kew for examination. Massee examined the spots and was of opinion that the spotting was due to the fact that the fruit had been subjected to too high a temperature at the period of ripening, and that the cells were killed by fermentation.

Gussow (14) in 1906 reports the occurrence of the disease in apples grown in Worcestershire in England. His examination of the spots revealed the fact that the cells in the diseased areas were larger than the normal cells, and that the cell walls were thickened and dark coloured. Abundance of starch grains were also noted as lining the diseased cells Gussow points out that Sorauer has observed that the disease was very prevalent on the Continent in 1904, which happened to be a very dry season. He also draws attention to the fact that an unusually dry summer was experienced in Worcestershire when the injury appeared there, and on these grounds accepts Sorauer's interpretation of the disease, that it is brought about through the want of water not being able to supply the necessary sap for the development of the fruit, " so that some groups of cells, deprived of their food, become exhausted."

Farmer (15) in 1907 gives a short note on his acquaintance with the spot trouble. The presence of starch in the affected cells appears to him to be of great interest, and he thinks rather points to the action of the diastase being locally inhibited. He is of opinion that the disease is due to " obscure physiological causes, which can only be investigated on the spot."

McAlpine (16) in 1907 in his report on the disease in Australia says : " With regard to bitter-pit, the effect of various manures on this condition has been tried for a number of years, and while none have proved perfectly satisfactory, it has generally been found that a complete manure, containing nitrogen, phosphoric acid, and potash, aggravates the disease. In some experiments carried out last year on the Bismarck variety, the application of dissolved bones containing nitrogen and phosphoric acid only seemed to give the best result."

Brooks (17) in 1908 in a paper entitled " The Fruit Spot of Apples," describes two distinct troubles found in New Hampshire apples, which he distinguishes as the fruit pit of apples and the fruit spot of apples respectively.

With regard to the former disease, Brooks has little to say. The characteristic appearance of the disease is given, and the spots are noted as being closely connected with the vascular bundles. The cause of the spotting is ascribed to abnormal physiological conditions and a loss of water from the tissue. Brooks also studied the disease in apples from Maine, Michigan, and New York, from Ottawa, Canada, and Capetown, South Africa.

The latter disease, known as the fruit spot of apples, Brooks considers is due to a parasitic fungus, *Cylindrosporium pomi*, Brooks.

Sorauer (18) in 1909 describes the trouble as one common in Europe, especially in loose soils in dry seasons. He thinks that owing to premature dryness of the soil, the necessary quantity of organic material is prevented from reaching the developing fruit, whereby certain groups of cells are starved, and quickly perish.

Names of the Disease.

I shall now pass on to my own observations and conclusions regarding this disease.

Bitter-pit, stippen, stipp-fleche, Baldwin fruit spot, the brown spot, and dry rot of the apple are names applied to a curious spotting of the fruit which commonly occurs in South Africa and many other parts of the world. It is a defect not confined entirely to the apple, but is occasionally seen in pears and quinces. As it is so commonly found and well known in apples, this report is confined to a study of the disease in these fruits alone.

Geographical Distribution.

From the available literature it is clear that this trouble was known at least twenty years ago in Australia, America, and Europe. In Australia it was first thought that the "brown spotting" of apples was due to a puncture by the Harlequin fruit bug, but closer examination showed that this was not so. In America the sunken spots of the Baldwin apple were primarily associated with a fungus, while in Europe the spots were ascribed to too great a concentration of sap following a loss of water.

Bitter-pit is now commonly found in apples from Canada, United States, California, Mexico, Australia, New Zealand, Tasmania, and Europe. It occasionally occurs in apples grown in England and Madeira. From enquiries which I have made it does not appear to be prevalent in India. In South Africa bitter-pit occurs practically wherever apple culture is carried on.

Apple Culture in South Africa.

Before describing the disease, it will be well to say a few words regarding apple culture in South Africa. Cape Colony is at the present time the chief apple-growing centre, though there are undoubtedly large portions of the high veld throughout South Africa eminently suited to this fruit. It is only within the last twenty years that choice varieties of the best sorts have been grown in anything approaching a commercial scale. Prior

to this, only three or four varieties, which apparently had little to recommend them—beyond the fact that they were Cape seedlings—were cultivated, and these were mostly propagated by runners. To-day I think we might estimate roughly that the value of apples grown in South Africa would be about £30,000. Owing to the depredations of the woolly aphis or American blight (*Schizoneura lanigera*), it soon became imperative that all the introduced varieties should be on blight-proof stocks, and for this purpose stocks of Northern Spy, Winter Majetin, and French Crab have been almost exclusively used up to the present day. The Northern Spy stock is preferred by some on account of its vigorous and erect growth, with its compact, fibrous root, whereas others use the Winter Majetin, as it makes a horizontal spread of branches and possesses long straggling roots. Both these varieties are found to transmit their vigorous habit of growth to their scions, and when this is considered non-advantageous the difficulty is most frequently met by producing a dwarfing effect by grafting in a Paradise Doucin scion. Then upon this intermediate bearer the desired variety is grafted or budded.

In the Western Province of Cape Colony, where the rainy season comes on in winter, most of the orchards are under irrigation, and I shall here describe the conditions prevailing at perhaps the largest orchards in this particular part of the country, where I had an opportunity of making most of my field observations on this disease, and from which most of the fruit was supplied for its investigation.

The Hex River valley is situated at about 1,300 feet above sea level. It runs, roughly, east and west, with mountains on each side, ranging from 7,500 to 4,000 feet. The soil in the valley is chiefly of a sandy nature and various analyses showed that the percentage of silica varied from 88 per cent. to 97 per cent. The native vegetation in the valley is of a decidedly xerophytic character. No fog or rains occur in the valley after October. The apple trees blossom in October, and the fruit is plucked in February and March. During the daytime intense heat is often experienced, both from the direct rays of the sun and also from the radiation from the hot sandy soil. Nearly every afternoon during the summer months a breeze springs up and blows up the valley from the south-west to east. The nights are always cool. The apples which first show evidence of bitter-pit are frequently those which are most exposed to sun and the prevalent winds. During the growth and development of the fruit, these orchards are usually irrigated every ten to fourteen days. Irrigation is carried on right up to the time that the fruit is ripe. The trees are planted twenty feet apart, and number one hundred to the acre.

In these orchards three common troubles are found in the fruit. They are sun-scald, water-core, and bitter-pit. Sun-scald is simply the result of the injurious action of the intense heat set up in the apple by the direct rays of the sun. Water-core, which is extremely common, is undoubted evidence of water exudation under pressure. The cell sap fills the cells to overflowing, but instead of bursting them, quietly diffuses through their membranes or walls and then accumulates in the intercellular spaces. In the majority of cases it finds its way to the exterior by exuding through the cuticle, where it appears in the form of drops of a sticky fluid on the surface of the apple.

Varieties of Apple Affected.

It is practically impossible to make an accurate statement regarding the relative immunity or otherwise of the many varieties of apples now grown in South Africa, for it is of no uncommon occurrence to find that varieties which are clean one season become badly spotted the next.

Mr. Dicey, of the Cape Orchard Company, Hex River, has been good enough to supply me with the following data regarding the amount of spotting in their apples so far as their observations extend for the last four years :—

1904.

Very Bad.	Bad.	Slight.	Clean.
Adam's Birthday	Anne Elizabeth	Ballarat Seedling	Cellini
Cornish Gilliflower	Cox Orange Pippin	Black Prince	Bismarck
D. T. Fiske	Irish Peach	Blenheim Orange	Devonshire Quarenden
Northern Spy	Keswick Codling	Beauty of Kent	Emperor Alexander
Wolsey.	Warner's King	King of Tompkins	Nonpareil
	Winesap.	Rome Beauty	Golden Russet
		Rhode Greening	Gravenstein
		Sturmer Pippin	Jonathan
		Tower Glamis	King Pippin
		Versfeld	Ohenimuri
		Wilson's Royal.	Reinette du Canada
			Simon's Winter
			Stone Pippin
			Takapuma Russet
			Wellington
			Worcester Pearmain
			Lamb Abbey Seedling.

1906.

Very Bad.	Bad.	Slight.	Clean.
Beauty of Kent	Blenheim Orange	Black Prince	Ballarat Seedling
Cornish Gilliflower	Cox Orange Pippin	Jonathan	Cellini
Devonshire Quarenden	Monmouth	King of Pippin	Golden Russet
D. T. Fiske	Rome Beauty	King of Tompkins.	Gravenstein
Red Astrachan	Ribston Pippin		Newtown
Reinette du Canada	Wellington		Ohenimuri
Rhode Greening	Winesap.		Simon's Winter
Sturmer			Stone Pippin
Spy			Takapuma Russet
Versfeld			Worcester Pearmain
Wilson's Royal			Lamb Abbey Seedling.
Wolsey.			

Very Bad.	Bad.	Slight.	Clean.
Devonshire Quarenden	Blenheim Orange	Cornish Gilliflower	Adam's Birthday
D. T. Fiske	Rome Beauty	Jonathan	Ballarat Seedling
King of Tompkins	Versfeld	Lamb Abbey Seedling	Cellini
Ribston Pippin	Wolsey	Ohenimuri	Golden Russet
Spy		Reinette du Canada	Gravenstein
Sturmer Pippin		Rhode Island Greening.	Irish Peach
Wilson's Royal.			Keswick Codling
			King of Pippins
			Ked Astrachan
			Simon's Winter
			Stone Pippin
			Takapuma Russet
			Wellington
			Winesap
			Worcester Pearmain.

In 1905 the Northern Spy was said to be very bad, Wolsey bad, and Reinette du Canada slight.

A glance at the above table will show that although some varieties are undoubtedly worse than others, for example, Northern Spy, D. T. Fiske, Wolsey, and Versfeld, yet other varieties, such as Adam's Birthday and Cornish Gilliflower, which were very badly affected in 1904, were reported clean in 1907, or only slightly affected.

Mr. Dicey has also been good enough to supply me with the following estimate as to the percentage of apples affected by bitter-pit within the last three years :—

In 1906 between 40–50 per cent. were affected.
In 1907 between 40–50 per cent. were affected.
In 1908 between 5–10 per cent. were affected.

Speaking of the small percentage of infections in 1908, Mr. Dicey says : " I think that I have already informed you that last year we had an exceptionally heavy crop of apples, heavier than we have ever known it before, and the presence of so little bitter-pit would seem to confirm your theory as to the cause, there being sufficient scope for the sap in the unusually large crop without bursting any of the cells."

The general experience throughout South Africa so far as my observation and information go is that the large sappy varieties which ripen quickly are especially liable to bitter-pit, whereas the smaller and firmer fleshed varieties are not so subject to it.

I have only met with two varieties of apples which can with any degree of accuracy be regarded as immune to the spotting. They are both of local origin, they have originated as Cape seedlings, and have been grown in the country for years. They are known locally as the Koo and Wemmers Hoek, they are usually grown on their own stocks, and are propagated by means of runners or in-layers.

Mr. Dicey, Manager of the Cape Orchard Company, has written me as follows regarding the Wemmers Hoek apple: "I have bought many thousands of bushels of this apple, grown in this valley, and from all parts of the Western Province, and I have discovered so little bitter-pit in them that I look upon them as being practically immune. This peculiarity in this special variety (Wemmers Hoek) seems worth investigating. I cannot call to mind any other apple which has shown similar immunity."

The Wemmers Hoek apple is said to have arisen from seed sown on the farm Wemmers Hoek, of the late Johannes Haumann, of French Hoek, in the Paarl District of Cape Colony, over a hundred years ago. The original tree is, I understand, still standing there to-day, and is propagated by in-layers.

For information regarding the Koo apple, I am indebted to Mr. S. G. Burger, of De Doorns, Cape Colony. This gentleman says: "The Koo apple is a tree known for the last fifty years on the farm Concordia, near Montagu, Cape Colony. As far as I can trace it back, it originated from seed, and was not imported, as the places at that time were inhabited by simple Dutch families; old inhabitants told me that they originated from seed."

Both these varieties are said to be blight-proof.

There is one other variety of apple in South Africa which I am informed on reliable authority remains free from bitter-pit, but as I am unfamiliar with it I give it with some diffidence, although it is worthy of special note that this variety also—the Bokveld—has undoubtedly arisen as a Cape seedling.

My observations on apples grown in the Transvaal are similar to those in Cape Colony—all introduced varieties are subject to bitter-pit, and perhaps much more so than those grown at the Cape, for it is no uncommon thing to see the total crop affected, whereas no trace of the spotting can be found in such apples as the Wemmers Hoek or unnamed South African seedlings growing alongside.

Characteristics of the Disease.

Although bitter-pit is commonly regarded as a trouble associated with stored apples, it is by no means infrequently found in the orchards before the fruit is ripe, or even full-sized. Its appearance amongst the fruit on a tree is very erratic. In some cases, one apple out of a bunch only is affected, while in others all the apples in a cluster are spotted. No hard and fast rules can be laid down as to calculations made regarding the size of the fruit that are affected, for both large and small apples develop the spots, although most frequently it is the larger fruits that first show the trouble.

Externally, bitter-pit may be recognised by the presence of dark-coloured depressions—varying in size from one-eighth to half an inch across—on the surface of the apple, and especially towards the apical end of the fruit (see Plate I). On slicing the fruit across, these dark depressions of pits are found to be composed of brown patches of tissue, which are considerably tougher in texture than the surrounding healthy

parts, for on cutting a ripe apple across, these spots frequently tend to tear out wholesale when they meet with the knife edge. When a clean cut is made across one of these necrotic areas they almost invariably show even to the naked eye a frothy or very spongy texture. The spots are not confined to the periphery of the apple, but are distributed throughout almost to the core (see Plate II). The external depression or pit is brought about by the collapse and coalescence of the cells comprising the brown tissue. Connected with these spots internally a discoloured vascular bundle is nearly always found. If a thin slice of apple about an eighth of an inch in thickness is taken and then left for a few days to dry, the brown spots remain standing up prominently above the rest of the tissue, clearly exhibiting the toughness and firmness of their composition, and when examined with a lens the spongy meshwork is very evident. The brown tissue is frequently found in apples which externally look quite healthy.

Microscopical Examination of the Brown Spots.

When the brown spots are examined microscopically, they are found to be composed of larger and thicker-walled cells than occur in the healthy tissue. A great number of these cells are ruptured and broken down, so that the opposite walls have collapsed and lie flat against one another, and at the same time imprison numerous starch grains between them (see Plate III). These ruptured walls are coloured brown with a gummy or mucilaginous substance, which is of a pectic nature, as is shown by micro-chemical tests and stains. No evidence of lignification, cuticularisation, or suberisation could be obtained.

These walls are not readily soluble in concentrated sulphuric acid, nor are they stained blue or violet with iodine and sulphuric acid, or with chloroidide of zinc.

In tracing the development of these brown spots, it is found that they always arise in close connection with the vascular bundles, and especially at the ends of the bundles. The cells bordering on the bundles are the first to enlarge and burst, as is seen in the micro-photographs. If a thin slice of an affected apple is treated with iodine a distinct blue colouration appears only in the neighbourhood of the spots, and this on closer examination is seen to be due to the imprisoned starch grains within the collapsed cells. A careful study of these starch grains reveals the fact that they are part and parcel of the original starch formed in the cells, and are not a secondary product resulting from the conversion of the sugar into starch by any new growth such as sometimes occurs. The establishment of this fact is of importance, as it proves conclusively that the injury to these cells occurred before the ripening of the fruit. These facts, together with the general appearance of the spots, leads me to conclude that this unhealthy condition of affairs is brought about by the following sequence of events. The cells surrounding the vascular bundles or those commonly situated at their ends are being continually subjected to great internal pressure, with the result that they become enlarged and thicker-walled. This internal pressure is undoubtedly due to an accumulation of water, which inflates the cells to such a pitch that in many cases

the tension becomes so great that the cells can no longer withstand the strain put upon them, and consequently burst. As soon as the cell is ruptured atmospheric oxygen gains access to the cell and, together with the enzymes present, act on the tannin, producing dark-coloured oxy-compounds, which are precipitated on the walls as a gummy substance, while any further diastatic action is inhibited, with the result that the starch grains remain unaltered, and are always abundant in the vicinity of the necrotic areas. As soon as a few of the cells bordering on the vascular bundles or those situated at their ends are ruptured, their neighbours surrounding them and depending upon them for their water supply are immediately affected, and consequently suffer also, with the result that a nest of unhealthy and dried-out cells becomes one of the dry and tough bitter-pit spots. The collapse of these cells in the interior of the fruit eventually leads to the characteristic depression or pit on the exterior.

Possible Causes of Bitter-Pit.

Various theories have been advanced from time to time to account for this trouble, and since it occurs in so many different parts of the world under such diverse conditions of soil, each has in turn been considered in so far as it was possible to test or disprove them, although it is extremely probable that no one factor alone is responsible for the spotting.

The following causes have been suggested :—

(1) Bacteria and fungi.
(2) Insects.
(3) Unfavourable soil and atmospheric conditions.
(4) Unfavourable grafting.
(5) Mechanical injury.

Bacteria and Fungi.

An exhaustive examination of many hundreds of spots by the most modern methods of microscopical technique failed to demonstrate the presence of either bacteria or fungi, and all attempts to obtain any growth of such organisms from the diseased areas by means of culture media entirely failed. Trees which bore affected fruits were to all intents and purposes perfectly healthy. Root, shoot, and leaf system, when examined, showed no evidence of harbouring fungi or bacteria, but appeared in every instance to be performing their normal functions.

Insects.

One of the earliest theories brought forward to account for the spotting was that the injury was due to insect puncture. This was soon afterwards disproved by the original proposer, but since then similar explanations have been frequently advanced. However, the most careful microscopic examination fails to reveal any trace of external injury, and to one well acquainted with the trouble, no such explanation would account for the isolated and deap-seated spots, such as are seen in Plate II.

Unfavourable Soil and Atmospheric Conditions.

Soil and atmospheric conditions may be conveniently considered together, and may be regarded as those causes which are due to the action of the non-living environment. The spotting is frequently attributed to unsuitable soils, especially those of a light nature, although little explanation is given as to why such soils should bring about this peculiar condition. In Europe it is thought that it is the sudden drying-up of these soils in times of drought that is responsible for the trouble, but in the light of my own observations it seems only reasonable to suppose that this is due to the fact that in such a climate the spots are then more noticeable, owing to the drying-out of the groups of cells which have been cut off from their water supply through the bursting of the cells bordering on the vascular bundles at a much earlier period. There is little doubt but that those climatic conditions which bring about excessive transpiration are largely conducive to the production of the spotting.

Unfavourable Grafting.

Before we can clearly understand any disease, we must be thoroughly acquainted with the processes by which it is brought about, and the unravelling of this particular disease is complicated by the fact that little reliable information can be obtained regarding the history of the plants that bear the diseased fruit. Especially for the elucidation of a trouble of this kind is a thorough knowledge of the whole plant's working system almost essential, and when it is remembered that the stock has probably been grafted over two or three times or even more, then will it be realised that the problem is more intricate than would appear at first sight. For instance, if the stock contains a greater number of vessels than its scion, then it is only natural to expect that the normal physiology of the latter may be deranged through the anatomical peculiarities of the former, and *vice versa*. Now, most of our apple trees in South Africa are grafted on Northern Spy stocks, a tree which is notoriously susceptible to bitter pit, and we are here again face to face with the question as to how far the stock is able to influence its scion; whereas we find that Colonial varieties propagated by runners are free from the trouble. In a climate with such varying and rapid extremes of temperature as is experienced in South Africa, there must be perfect harmony between root and shoot system, so that the one may regulate to a nicety any abnormal state of affairs set up within the tissues of the other. For instance, if a scion with a very high rate of transpiration be grafted on a stock of relatively slow root-absorption power, or if a scion with a low transpiratory action be grafted on a stock of great absorption power, it stands to reason that the working relations between the two will become somewhat distorted.

Mechanical Injury.

The chief theory under this heading that has been advanced to account for the trouble, is that the injury was brought about by blown sand. It requires very little, however, to disprove any such proposi ion, when it is remembered that a great number of the spots do not take their origin from the exterior, but are found deeply seated in the internal flesh of the fruit.

Summary and Conclusions.

Bitter-pit is an abnormal spotting of the fruit of the apple. It results from the bursting and consequent breaking-down of certain cells of the flesh due to too great internal pressure. This great pressure is set up by the external conditions to which the trees are exposed. These trees are not of themselves plastic enough to adapt themselves to their environment, and thereby regulate their physiological functions, with the result that abnormal forces are brought into play with which the plant is unable to cope in the ordinary course of events. In consequence thereof abnormal physiology leads to disease conditions. The main factors that are responsible for the spotting are believed to be excessive transpiration during the day, followed by its sudden checking and complete abeyance during the night, when root action is still vigorous owing to the warmness of the soil. Under these circumstances water accumulation takes place to such an extent in the cells of the fruit that an actual bursting of the cells may occur.

Although the results obtained thus far are in the main negative, from my study of this disease I am unable to offer any ready remedy for the evil, yet I can suggest lines upon which the apple grower in this country should proceed if he is to succeed with the cultivation of this fruit. One of the most significant facts in connection with this investigation is that only those varieties of apples which escape bitter-pit and which show immunity towards it are those which may be described as Colonial apples. The best known amongst these are the Koo, Wemmers Hoek, and Bokveld, and they undoubtedly originated from seed sown in this country. This being so, it is worthy of our best attention, and it is in this direction, I am convinced, that the future establishment of our apple industry lies; that is to say, we must raise our own varieties in this country and not endeavour to grow foreign apples here, under the impression that because certain foreign conditions appear similar to ours, fruits from those regions will be suited to our climate. Climate is the most important factor with which we have to reckon in the cultivation of our plants; in fact climate practically determines the character of all plants in any geographical region. Consequently, when we introduce a plant into any given geographical region, it either flourishes or dies. If the former case occurs, we know that the climate is congenial; if the latter, then we understand that the plant has not been plastic enough to adapt itself to its surroundings. Now it may well be asked, but how is this adaptation to environment best brought about. It can only be done by following out nature's methods, namely, by producing offspring which will be best fitted to their surrounding conditions.

We have then to make a clean start in this country so far as our apples are concerned, and we have to raise South African seedlings in the localities in which we wish to plant our orchards. By this means alone it is firmly believed that the present difficulties will be overcome. In support of this statement I have only to refer to the experience and present status obtained in American horticulture, not only with the apple itself but with many other familiar fruits, and from which it is abundantly clear that

the best American apples to-day, as well as their other fruits, are those which have originated in the country as seedlings, and which have at the present time almost entirely supplanted all foreign introductions.

In conclusion I would like to take this opportunity of expressing my thanks to Mr. C. P. Lounsbury, Cape Government Entomologist, the Cape Orchard Company, Mr. Herbert Ingle, and Mr. R. A. Davis, Horticulturist to this Department, for the valuable information and assistance which they have rendered me in the carrying out of this investigation.

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Description of Plate I.

Laxton's Schoolmaster apple, showing the external appearance of the bitter-pit spots. The pits or depressions on the surface of the apple caused through the collapse of the cells in the bitter-pit spots beneath the epidermis are clearly seen.

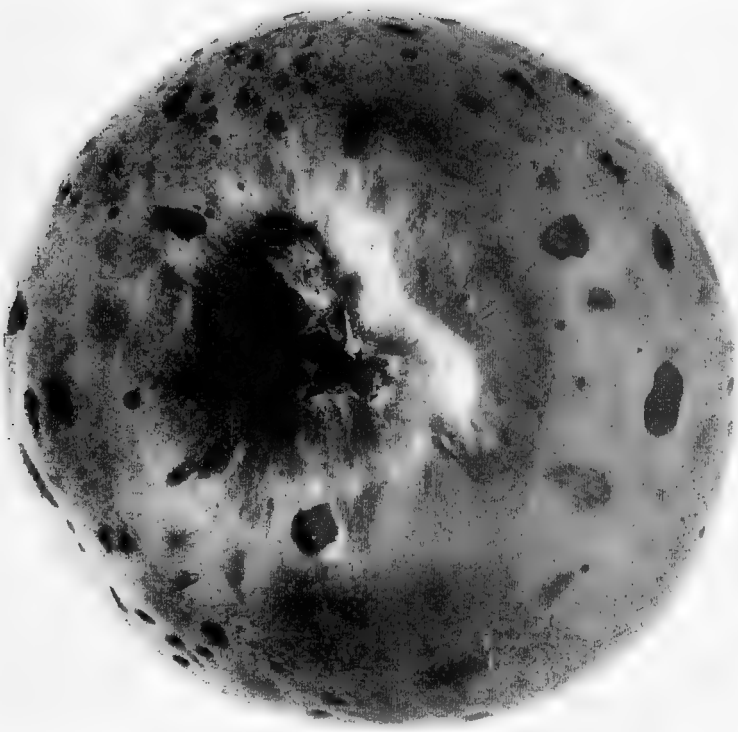

Plate I. Apple affected with Bitter-pit. External appearance.

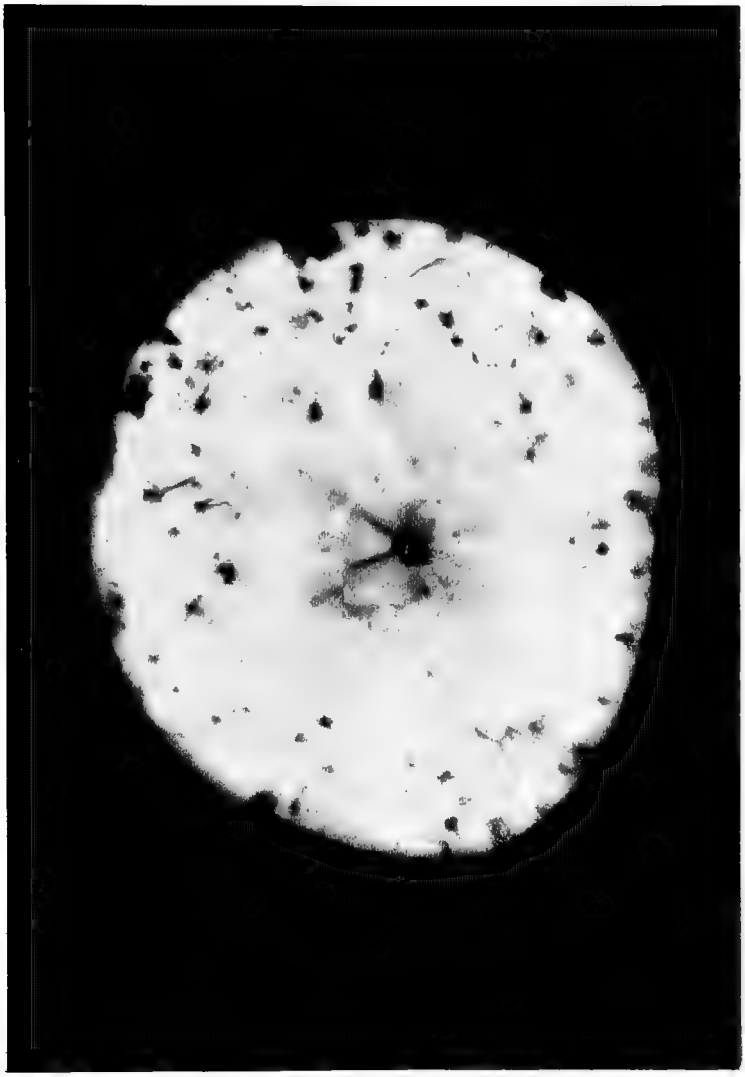

Plate II.—Apple affected with Bitter-pit. Internal appearance.

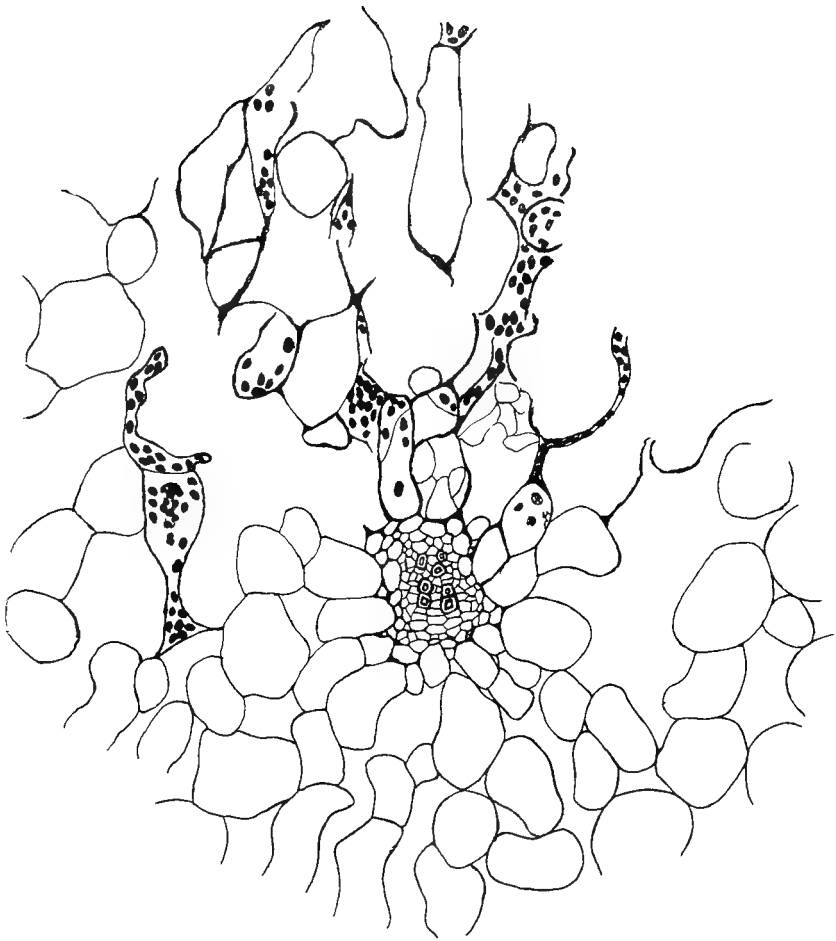

Plate III.—Section through a Bitter-spot in the neighbourhood of a vascular bundle.

Fig. 1. Fig. 3.

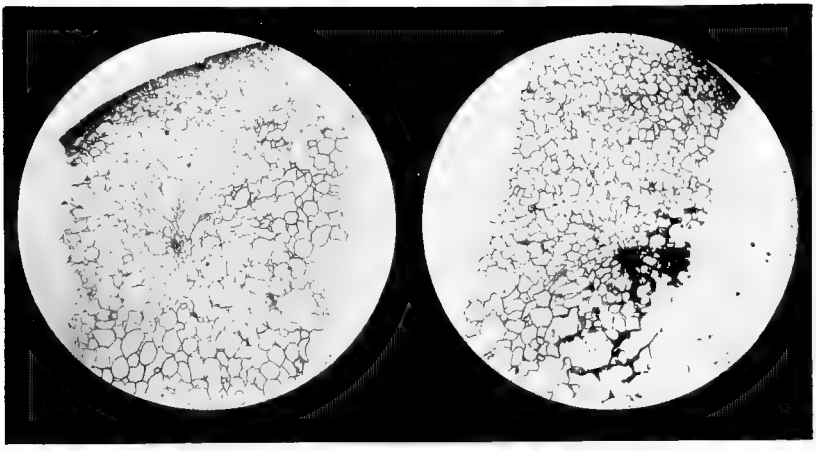

Fig. 2. Fig. 4.

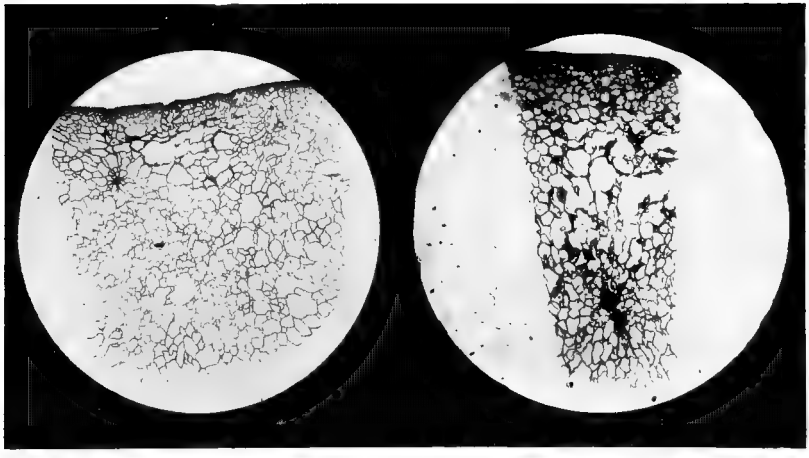

Plate IV.—Sections through Bitter-pit spots at various stages of development.

Fig. 1. Fig. 3.

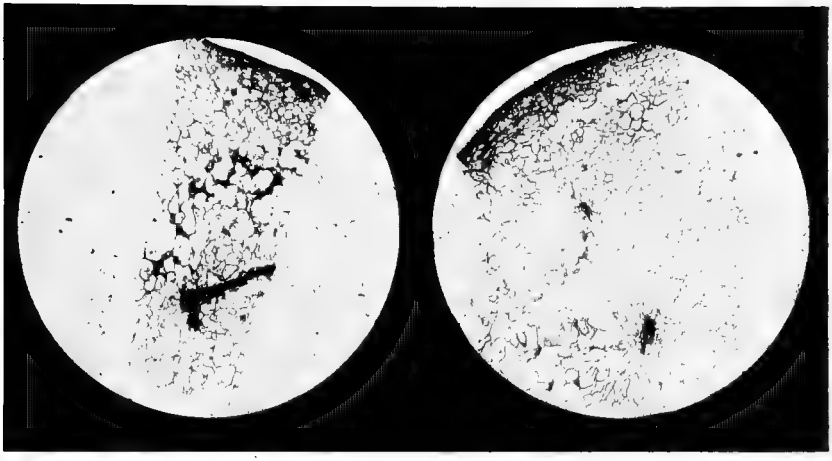

Fig. 2. Fig. 4.

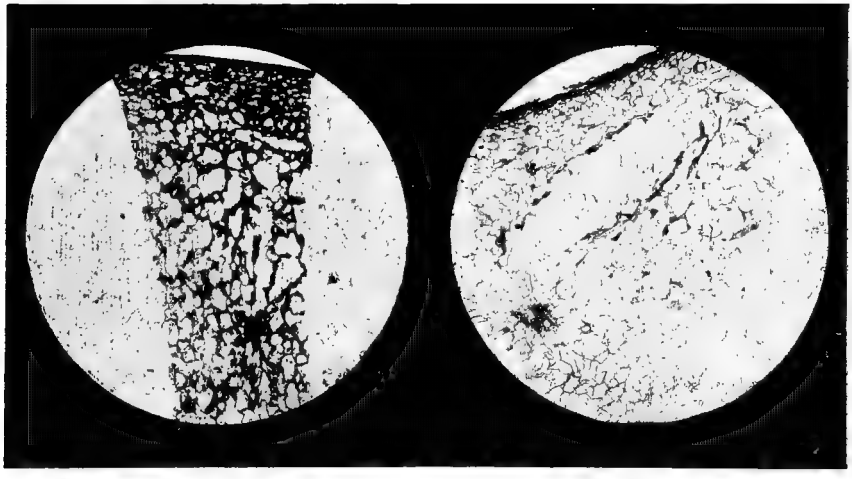

Plate V.—Sections through Bitter-pit spots at various stages of development.

Description of Plate II.

Versfeld apple affected with bitter-pit cut across transversely, and showing the distribution of the spots within the tissue of the apple. A number of these spots are seen to occur well within the interior of the apple, and are also closely connected with discoloured vascular strands.

Description of Plate III.

Section through a bitter-pit spot in a Versfeld apple. A vascular bundle is cut across transversely, and in close connection with it at the upper part of the section is shown the general appearance of the enlarged and collapsed cells with their enclosed starch-grains such as are usually met with in the bitter-pit spots. In the lower part of the section the normal cells are shown, and it will be seen that they have thinner walls, are devoid of starch-grains, and are of smaller size than those which compose the bitter-pit spots.

Description of Plate IV.

Fig. 1.—Micro-photograph of a section through a part of "Lord Wolsey" variety. A vascular bundle is cut across transversely, and surrounding it a number of the cells are seen to be enlarged, and a certain amount of bursting and collapse has taken place.

Fig. 2.—Micro-photograph of a section through a bitter-pit spot at an early stage of its development. A vascular bundle is cut across transversely, and leading away from the bundle to the right is a mass of broken-down cells, which have numerous starch grains imprisoned between the collapsed walls. Owing to the low magnification used, the individual starch grains cannot be clearly made out in the micro-photograph. (Lord Wolsey variety.)

Fig. 3.—Micro-photograph of a section through a bitter-pit spot in the Versfeld variety. The collapsed and broken-down cells are seen to be closely connected with a vascular bundle, which is cut across transversely.

Fig. 4.—Micro-photograph of a section through a bitter-pit spot in the Versfeld variety. Between the epidermis and the vascular bundle the necrotic area is clearly seen. The cells in this region have thicker walls than those in the surrounding healthy parts. Some of them are very much enlarged, while many have collapsed, leaving large irregular intercellular spaces. The vascular bundle seen in transverse section is closely associated with the diseased spot.

Description of Plate V.

Fig. 1.—Micro-photograph of a section through a bitter-pit spot in the Versfeld variety. The vascular bundle is cut through just at the point of branching, and is seen partly in transverse section and partly in longitudinal section. The diseased cells can be traced directly to the bundle.

Fig. 2.—Micro-photograph of a section through a bitter-pit spot in the Versfeld variety. The collapsed and thick-walled cells are seen to arise from the vascular bundle which is cut across transversely. Numerous starch grains are present between the collapsed walls, but owing to the low magnification used are not visible in the photograph.

Fig. 3.—Micro-photograph of a section through a bitter-pit spot at an early stage in its development in the Lord Wolsey variety. The vascular bundles in the tissues are cut across transversely. Arising from the upper bundle some enlarged cells are seen, as well as the broken ends of several burst cells.

Fig. 4.—Micro-photograph of a section through a bitter-pit spot at a fairly advanced stage in its development. Its close connection with the vascular bundle is clearly seen. The indistinct dark masses amongst the broken-down cells are composed of numbers of starch grains imprisoned between the cell walls. (Lord Wolsey variety.)