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MEMORANDUM

UPON

POTATO DISEASE:

ITS HISTORY, NATURE, AND PREVENTION.

PREPARED FOR THE INFORMATION

OF

BOARDS OF GUARDIANS.

BY

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POTATO DISEASE:

ITS HISTORY, NATURE, AND PREVENTION.

PART I.—PRACTICAL.

PREVENTION OF POTATO DISEASE BY THE APPLICATION OF SULPHATE OF COPPER AND LIME.

In order to prevent the spread of potato disease, several points demand attention from time to time. The disease commences in various ways, by far the most common being an external attack upon the leaves and tops, followed by the penetration and destruction of the plant. Against this mode of attack, the grower is now enabled to protect his crop by the use of the spraying machine, and the application to the foliage of one or other of the chemical mixtures, specially prepared for the prevention of fungoid disease.

The Bouille Bordelaise, which is a solution of sulphate of copper and lime in the proportion of 20lbs. of copper, and 10 lbs. of unslaked lime to 100 gallons of water, has been for several years used with signal success for the prevention of phylloxera in continental vineyards, and during the past few years it has been adopted to check potato disease in the United Kingdom.

The mixture is applied in the form of a fine spray by a machine specially adapted for the purpose. No matter how fine the spray, as long as the leaf is protected by the slightest film of sulphate of copper, the germ-thread of the minute fungus seed will not attempt to enter it. When the leaf is in a healthy condition, the germ-thread at once becomes aware that it is in a suitable place to establish itself and it works its way into the layer of living cells. A coating of sulphate of copper on the leaf has a deterrent effect on the fungus. Hundreds of these little seeds may fall on the leaf but not one will attempt to enter it if it has to pass through the obnoxious chemical. The leaf is protected by a safe armour.

The dressing may not stop the disease when it is actually in the plant, but it will prevent any spread by fresh attack. *The point to be observed then is to keep the disease out of the plant.*

When to Spray.—The first attack in every season is caused by the winter seed hatching out on the surface of the ground, or in heaps of rotten and rotting vegetable matter, and being carried by the wind from place to place and plant to plant. The safety of a crop is imperilled if one of these seeds alight on a potato plant and commences to grow, for one of them will, in the course of a few days, produce millions of seeds, and these millions will produce their millions, until the whole country is in danger. To prevent this it is necessary to protect the crop while it is young—in other words, to have it encrusted with copper before the winter seeds are hatched by the warmth of summer.

Before the ordinary observer is aware of it, the disease has always been in the field for some days—often for some weeks.

It is not recognisable under casual observation until it has developed to such an extent, that, should the weather continue moist and humid, the whole crop may be affected unless the special provision of protection by spraying has been resorted to.

If the weather be cold or dry, the disease may be in the field for weeks without doing serious damage, but, on a change to warmth and moisture, the devastation is at once commenced. If the crop has not been already protected, no time should be lost in applying a good dressing. If, since the date of the first dressing, a considerable growth of haulm has taken place, a second dressing should be promptly applied. In exceptional seasons when the weather continues warm and humid—mushroomy weather, as it is often called—a third dressing may be advisable, but such occasions do not often occur.

It is advisable to commence spraying so soon as the tops of the potatoes have recovered from the bruising they received when being earthed up. Should the weather be persistently dry, the operation may be delayed until the approach of rain.

It would be not only unwise, but misleading, to suggest any special day, or even week, as the best time for the first spraying. Had we the means of foretelling to a nicety the movements and programme arranged by the fungus, our advice would be to spray your crop the day before the seeds of disease take wing, This, however, is beyond our power, for the disease is developed by meteorological conditions over which we have absolutely no control. Farmers have learned by sad experience the period about which blight generally reveals itself, and observant persons can, by studying the weather and referring to the records of the past, arrive at conclusions sufficiently reliable to determine their action in the matter of when to spray.

Be it ever remembered that the seeds of disease require but two inducements—heat and moisture—to endow them with life and liberty. The safety of the potato crop will be best secured by a prudent resolve on the part of the farmer to have his crop protected the instant he considers the disease seeds are assuming, or are likely to assume, an active form.

Generally speaking, the first spraying should be done between the 20th of June and the 10th of July. The earlier the locality and the season, the earlier should the dressing be applied. *Better by far to be a week before the disease than a day behind it.*

The second dressing should be administered from four to six weeks after the first, but here again it is impossible to dogmatise, for the circumstances of the season and weather alone decide what should be done. So long as there is a possibility of a fresh attack, the leaves must be protected; and, should the first film of copper have been washed off, or otherwise dissipated, another must be supplied.

Too much emphasis cannot be placed upon the advantages which farmers will derive from carefully taking notes and discussing such questions among themselves. As the outcome of such co-operation it is certain that very important and valuable conclusions would soon be forthcoming.

Early and tender varieties should receive a light dressing of a mild solution of the mixture. It will be found in all probability that an application of seventy gallons of the solution two-

thirds the strength usually applied, or the full quantity of 100 gallons reduced to half strength will be most suitable for tender varieties when very young. For fair ordinary crops 100 gallons of the Bouille is required per acre, but if the crops are exceptionally big and weather very close and moist, 150 gallons may be necessary. It is not improbable that in certain extreme cases a stronger dressing of, say, 30 lbs. of sulphate and 15 lbs. of lime to 100 gallons of water might be advantageously applied.

The presence of the sulphate of copper prevents the disease. The lime is added for two reasons—1st, to produce an alkaline re-action on the sulphate of copper, neutralising its caustic or burning properties; 2nd, to make the solution adhere more securely to the leaf. The mixture already described is that in common use. However, having in view the inferior properties and insufficient burning of much of the lime, many farmers now mix 15 parts of lime with 20 parts of sulphate, and where the quality of the lime is suspected to be inferior, this is undoubtedly a wise precaution and worthy of adoption.

WHERE AND WHAT TO SPRAY.—A "perfect" spraying covers all parts of stem and leaf with a film of copper. Owing to the dense foliage and mass of undergrowth peculiar to the potato, and in great measure concealed from view of the operator, it is very difficult to effect at one and the same time a perfect spraying with the quantity of material adopted as being necessary and suitable. Some experienced sprayers recommend that only the upper surface need be dressed, alleging as their reason that the disease-seeds come to rest there, and that this is therefore their point of attack. Others, again, hold that as the threads of mycelium form towards the underside of the leaf, where also are situate the "stomata" or breathing pores whence protrude the branches which envelop the seeds of the disease in the form of ova or eggs, a dressing administered from below, and directed towards the underside of the leaf is the more effective.

A careful perusal of Part II. of this Memorandum will, it is believed, enable sprayers to decide for themselves which of the two methods to adopt. Should the dressing be applied before the leaves show any symptoms of being smitten, the best site for the reception of the copper will be those parts on which the disease-seeds are most likely subsequently to alight, in other words the upper surface.

If, on the other hand, there is reason to believe that the upper portion of the leaf has already been penetrated, and that the forces of the fungus are now actively employed towards the lower surface, a dressing from below, and directed upwards, should be relied upon.

Dressing from below is haphazard work when the haulms are rank, because the operator is toiling as it were in the dark, but when applied from above, whether the nozzle be pointed upwards or downwards, the sprayer sees well what he is doing.

A simple and effective plan by which a crop may be dressed, both above and below, is to go twice over the ground, applying half the quantity first to the under surface from below, then repeating the process to the upper surface from above.

In order to arrive at the proper speed to walk and quantity of solution to apply to the leaves, the apprentice should first measure out the proportionate number ofdrills or extent of lazy-bed for one charge of the vessel. When a dressing of 100 gallons is designed for a statute acre, and a 4-gallon machine in use, one vessel full should dress the 25th part of an acre or a piece of land measuring 21½ yards in length by 9 yards in breadth. The width of an acre in any field may be learned by dividing 4840 by the length of the drill or bed, and the width required for 4 gallons of solution (when 100 is allowed for an acre) is the width for one acre divided by 25.

How to Prepare the Solution.—The sulphate of copper should be broken into a fine powder, so that it will dissolve the more readily. It is absolutely imperative that the sulphate of copper should be pure. Sulphate of iron is often substituted or used as an adulterant. Good sulphate of copper should contain 98 per cent. of sulphate of copper, equal to 24·5 per cent. of metallic copper, and these proportions should be guaranteed by the seller. The genuine Bouille Bordelaise is of a deep sky-blue colour. When it assumes a green or a brown hue it is evident that a spurious article has been used. The lime should be freshly burnt and of good quality. All utensils must be made of wood, or they will soon corrode. The Bouille is poison and must be treated as such.

The sulphate of copper should be suspended in a bag into hot water; it dissolves more rapidly in this way than when lying at the bottom of the tub. Only a small quantity of warm water is necessary. While the sulphate is dissolving, the lime should be slaked until it is of a creamy consistency; then slowly pour the solution of lime into the solution of copper, taking care to keep it stirred during the operation.

Special Anti-pest Preparations are now made and sold in large quantities by firms of high repute, and these commend themselves to the very best attention of the public, for in them the farmer obtains a superior article ready for use and in convenient form for present and subsequent application. The use of these specially prepared mixtures does away with the necessity for many vessels, because being in the form of a powder or paste it dissolves with rapidity and certainty. Moreover, they form a distinct protection against error in the preparation of the mixture by ignorant or unlearned persons. These compounds are sold on guaranteed analysis, and under these circumstances they can be confidently commended.

SPRAYING MACHINES AND HOW TO MANAGE THEM.

Three different types of machines—manual or knapsack, portable, and horse-power—are now in the market. The manufacture of these machines is at present confined to a few firms and doubtless each has its advocates and supporters. It is not proposed to enter into the individual merits of any make or draw comparisons which might appear invidious. Boards of Guardians will doubtless in due time be supplied with full particulars and diagrams from the parties tendering for their

orders, and the Local Government Board will afford further information for the assistance of purchasing Unions, so far as will be consistent with their position of impartiality.

It may, however, be observed that simplicity of construction, absence of wearing parts, strength of build, and efficiency in working are all important elements worthy of consideration when arriving at a decision or making a selection.

The capacity of machines may vary, and it should be remembered that frequent replenishing involves loss of time, thereby increasing the cost of the operation and decreasing the quantity of crop dressed in a given time.

On the other hand, a cumbrous machine, whether manual or horse, may retard the progress of the operation and render frequent stoppages necessary. Granted that the weight of a fully charged machine is during work ever on the decrease, nevertheless excessive weight has its disadvantages.

Some manual machines may be more easily worked than others either from the position of the pump handle or from some mechanical superiority. Needless to say, ease in impulsion should not be overlooked.

Again some machines may be supplied with a means of obviating the accumulation of sediment at the bottom of the vessel, and this must commend itself as a vantage point over machines devoid of such.

The fineness of and area covered by the spray and the construction of the nozzle with its several attachments, should be very carefully studied, bearing in mind that the foliage should be thoroughly drenched as with a thin mist, and that multiplicity or complexity of parts is not only vexatious of itself, but a pregnant and frequent cause of interrupted progress. In complicated machines, bolts, nuts or springs are frequently lost, and they are sometimes difficult to replace. When any stoppage occurs through the presence of sediment in the duct leading to the port of escape, a readily detachable nozzle and easily probed duct would appear to be distinct advantages.

Portable Machines are so constructed that they can be attached to any ordinary farm cart. The receptacle for the solution consists of an empty paraffin barrel to which is fitted a pump and hose or pipe. This pipe leads to a distributing tube of sufficient length to dress five drills at one operation. The portable cart machine is said to have given excellent results, and it is highly probable that in districts where the drill system is practised one of these machines would serve the purposes of a considerable number of occupiers. Allowing an average of 7 statute acres per day for a portable cart sprayer, one machine would cover over 60 acres in nine days. Boards of Guardians proposing to hire machines out to farmers will do well to consider the advisability of purchasing one or two of these portable cart machines.

The Horse Power Machine is best adapted for large fields and long ridges, and as among occupiers at and under £15 such conditions seldom prevail, the machine now under notice can hardly be pronounced suitable or necessary.

In districts where the lazy-bed system is universal, no horse or portable machine can be utilized, and the attention of Boards of Guardians must, in such cases, be restricted to the purchase of

what in their estimation promises to be the best and most reasonably priced manual or knapsack sprayer.

It may be well to remind such Boards of Guardians as may decide upon purchasing portable machines with a view to hiring them out, of the benefits to be derived from the presence of a careful and reliable man expressly employed to superintend and conduct the work done for the people. Were the machine entrusted to the tender mercies of all applicants, it is difficult to anticipate what might not ensue in breakages or derangements of working parts. Indeed taking everything into practical consideration and remembering the importance of spraying in time and the fatal results of delay, it is suggested that the presence of a manager or superintendent, whose special duty it would be not only to take charge of the spraying done on hire but to execute repairs and keep a stock of duplicate parts for the machines (manual or otherwise) in use throughout the Union, would prove a veritable boon to Guardians and occupiers alike, a saving of expense and disappointment to all parties concerned.

It is usual among makers of spraying machines to supply with each machine a leaflet giving full instructions for working, and there is no reason to suppose that this custom will not be continued by contractors to Unions purchasing under the spraying clauses of the 1898 Seed Supply Act. Guardians should, however, caution their people upon the necessity for carefully treating and storing the machines during and after use. Before laying them aside, they should be thoroughly rinsed out and freed from all adhering solution, then thoroughly dried and packed up according to printed instructions.

SALES OF SPRAYING MACHINES TO OCCUPIERS BY BOARDS OF GUARDIANS.

Boards of Guardians may sell for cash either to individual occupiers of land valued at or under £15, or to several occupiers making joint application.

Should the latter course be entertained, it is well to explain that a knapsack machine of ordinary capacity worked with industry is capable of dressing one statute acre per day of ten working hours.

When several occupiers combine and assist one another, it will be found that in the long summer days more than an acre can be thoroughly dressed at the rate of 100 gallons per acre.

Allowing a fortnight as a safe and suitable period, at any time during which either first or second spraying may be applied, and deducting 5 days for bad weather, contingencies, and Sundays, it follows that one manual machine will suffice for the requirements of a group of occupiers whose joint acreage under potatoes does not exceed 9 acres.

In this matter Guardians must exercise their own discretion, for in exceptionally humid districts 6, 7, or 8 acres may be deemed a safer basis upon which to calculate. The ascertained facts as above stated will, however, be of some service in enabling Guardians to decide upon the number of machines required for their various Electoral Divisions.

One prominent danger of co-operative possession in a sprayer must not be overlooked. Procrastination or putting off time till the last moment will, if permitted, destroy the otherwise undoubted advantages of the movement. Against any such misfortune Guardians must determinedly contend.

By taking a personal interest in the first season's proceedings under the spraying clause, Guardians and Relieving Officers may bring about a complete fulfilment of the conditions necessary for successful and punctual use of the machines owned in common. There is every reason to conclude that the lesson once learned will not have to be relearned.

Disagreement among applicants as to who shall have the first and who the last use of the machine, cannot form a serious or lasting difficulty, for the simple reason that it is quite impossible to foretell which day of the allotted period may give the best results.

A solution to such a problem might be found by arranging the use of the machine in alphabetical order. The name first in order for 1898 would be placed last for 1899, and so on like a revolving ring or circle.

A few manual machines kept in the workhouse for hiring out, would prove useful and valuable for cultivators or cottiers. A charge per day or per hour would probably be the best mode of dealing with persons applying for machines on hire. An acreable charge would involve immense trouble and expense on Guardians when furnishing their accounts for spraying done, and would necessitate the employment of a land surveyor or measurer.

PART II.—HISTORICAL AND TECHNICAL.

Long before the potato was known to European cultivation, it grew, a wild plant, in the shady woods of tropical Peru. There in its native element it reproduced itself year after year, from its own tubers, without suffering from constitutional degeneracy or disease. Sir Walter Raleigh introduced the plant to the south of Ireland about the year 1600, but for a considerable number of years subsequent to its introduction it was regarded as a crop suitable only for garden cultivation—a luxury for the table of the rich rather than an article of diet for the poor. The potato seems from the very outset to have found more favour in Ireland than in the sister countries, for whereas in the year 1619 we find it referred to as "one of the articles provided at great cost for the use of the Queen of England's household," we also learn that in the time of the Commonwealth, 1649 to 1660, its cultivation had already spread over a large portion of Ireland. In the old statistical accounts of Scotland the plant is said to have been first cultivated as a field crop in 1739, in the county of Stirling, while the same authority states that until 1743 the potato was unknown in the Highlands and Isles of Scotland.

So long as its cultivation was confined to a limited area and conducted in simple and natural ways, the potato does not appear to have suffered to any appreciable extent from disease, consti-

tutional or epidemic, but as time passed and farmers adopted forcing and artificial methods of cultivation, the crop began to exhibit those tendencies to degeneracy and disease which in subsequent years were destined not only to terrify and alarm statesmen and economists, and bewilder phytologist and practical farmer, but to sweep whole fields and desolate entire districts.

Long before the first appearance of the terrible murrain or blight, the potato crop had been intermittently affected by such diseases as the "curl" and the "Bobbin Joan," but these evils appear to have been chiefly confined to certain narrow districts, and at no time to have wrought such wholesale and indiscriminate havoc as has accompanied the fungoid attacks of the past half century.

The history of the potato, past and present, teaches us very clearly that the constitution of a tuberiferous plant inducted from a tropical to a temperate climate, submitted to artificial modes of culture, and forced by such means to an abnormal degree of productiveness and precocity, eventually and invariably breaks down under the strain, and that a crop constitutionally broken down or degenerated falls an easy and a ready victim to any attack of mildew or fungoid disease. Scientifically ignorant as were our forefathers on the subject of fungus parasites, their practical experience and conclusions have been amply borne out by the experiments and discoveries of scientists and experts of modern times, and beyond the region of doubt or contradiction it has been proved—

(*a.*) That some varieties of potatoes are more susceptible of disease than others ;

(*b.*) That the longer a variety is cultivated the more susceptible does it gradually become ;

(*c.*) That when tubers to be used for seed are taken from crops wherein disease has been known to exist, the resulting crop will be specially prone to fungoid attack ;

(*d.*) That as a general rule the use of highly nitrogenous and stimulating manure has a tendency to develop fungoid disease ;

(*e.*) That a periodical change of seed and the cultivation of new varieties constitute in themselves valuable protection against degeneracy and disease.

From the foregoing remarks it will be seen that growers of potatoes may lessen the chances of serious damage from blight, by avoiding the use of worn-out varieties, giving a preference to those of recent introduction, and it may also be added that by careful attention to cleanly cultivation, the avoidance of overcrowding in drill or bed, the proper draining of wet lands, the planting of well-matured and strong seed, the storage of the crop in dry condition and well-ventilated pits, the prospects of the potato grower are further improved. But there is not nor has there been during the last fifty years such a thing as an absolutely "disease proof" potato known to cultivation. Many varieties have earned the reputation of being "disease-resisting" for a number of years, but even the most expert and successful of our raisers and seedsmen have failed to put on the market a

potato which could be guaranteed of its own inherent powers to entirely defy fungoid attacks. Indeed it is an acknowledged fact that prior to the introduction of the spraying process, potato growers in Ireland occupied at all times a position of great uncertainty, and in wet seasons of utter helplessness.

Where, however, practical skill and industry failed, science and the microscope have succeeded, and now we have for our information and benefit not only the history of the potato disease in full and minute detail, but the means of preparing for its advent and combatting it on its arrival.

It may safely be asserted that the beneficial results of spraying have never since the introduction of the practice been more plainly or forcibly demonstrated in Ireland than during the past season 1897. In all parts of the country remarkable success attended the operation, a success which revealed itself not only in a mitigation of the damage done by disease but in a large increase in the gross yield of the crop and a distinct improvement in the cooking quality of the tuber.

It is equally important to observe in favour of the system, that even in exceptionally dry summers when disease prevails to a limited extent and in unusually mild form, the benefit derived from spraying has been pronounced and significant. Mr. Malden, at page 151 of his valuable treatise on the potato, thus describes the results of experiments conducted in the dry season of 1893 by the Royal Dublin Society :—

> "We personally conducted a series of experiments in Ireland in the years 1893 and 1894. These experiments were carried out by thirty farmers in various parts of the country. The whole of the results were collected and the average struck, which showed that there was an average gain per acre of from one pound to forty-eight shillings according to the variety, after deducting fourteen shillings per acre allowed for two dressings, although in some cases only one was given. The increase was due to the potatoes being kept alive and in a growing condition after the unsprayed had withered. The striking feature in these results is that they were obtained in the dryest season on record in the country, and one in which the disease was very light ; in fact it was commonly stated that there was no disease in the country. Very few tubers rotted in any part of the country, and even on the duplicate plots alongside those which were sprayed there were rarely any diseased tubers. The haulm, however, was generally affected though it was not commonly realised, but the yield of tubers was lessened thereby."

The value of sulphate of copper as a protection against fungoid attack has long been recognised by agriculturists. The pickling or steeping of seed wheat as a means of securing the crop against the attacks of such fungoid growth as smut, bunt, or mildew has been practised by farmers for generations past. It is the more remarkable then, that not until 1888, long after the real character of potato disease had been ascertained, was any attempt made to test the efficacy of the chemical as a preventive of the fungoid blight to which the potato was so conspicuously a victim.

Dr. Fream, in his Elements of Agriculture, prepared under the authority of the Royal Agricultural Society of England, points out in reference to the pickling of seed wheat that :—

> "The effect of sulphate of copper or other antiseptic agents sometimes used, is not to destroy the spores of the fungus which indeed live through the application, but when the spores germinate the delicate young hyphae find themselves in a medium which is fatal to them and the disease is thus checked."

In this we have merely a parallel explanation of the method and process of salvation effected by the application of a copper solution to the potato crop not yet overpowered by phytophthora.

POTATO DISEASE—ITS NATURE AND MODE OF ATTACK.

The fungus which attacks potato crops was formerly known as Peronospora infestans; now it is recognised by scientific authorities as Phytophthora infestans. The appearance of the disease when a crop is attacked is unfortunately too well known to require description; the leaves turn brown and later on a strong putrid odour is recognisable even at a distance. Examine a plant in the early stages of the disease and small brown spots are noticeable about the leaf and stem. Unless these are carefully observed, there is nothing to indicate that they are not dying in the ordinary course of nature. Closer inspection, however, reveals the presence of a greyish line of mould or flocculence, just where the green and brown portions of the leaf unite, but especially on the under side of the leaf. This edging is in reality a streak of mould very similar to the naked eye to the mould which is noticeable on decaying vegetables, cheese, old boots and other familiar substances. The mould has a powdery appearance, but if examined under the magnifying glass, it will be seen that it is composed of an immense number of fine threads which occasionally branch, and that they carry at their extremities small ovoid fruits called "conidia." These branches or "aerial hyphae" spring from threads or roots of the fungus within the leaf, and are called, collectively, "mycelium" or "submerged hyphae." The fungus lives within the plant, feeds on its juices, ultimately breaking up its structure and causing the plant to die. In dry seasons the energies of the disease are restricted, but the scourge is never absent, and during wet summers the parasite does its deadly work on such a vast scale as to create potato famines. Moisture is a necessity of its existence, and in rotting haulm, decayed tubers, and damp soil the spores remain in a resting condition until they are afforded an opportunity of multiplying with the marvellous rapidity that invests the disease with its terrible power.

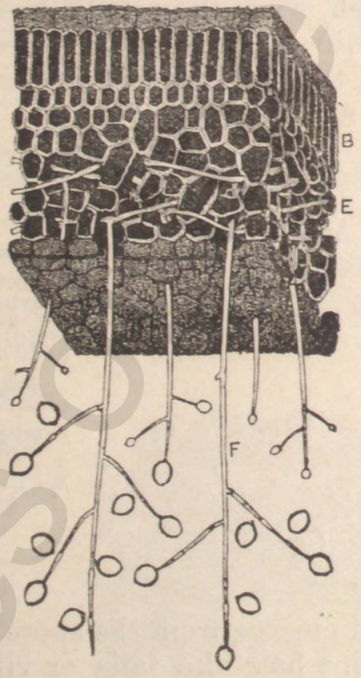
A series of six illustrations, five of which are highly magnified, will enable the reader to follow the development of the phytophthora.

Illustration No. 1 shows a potato leaf on a reduced scale marked by the attack of the fungus.

No. 1.

The phytophthora is here represented as sending threads in all directions through the substance of the leaf, tapping the cells and destroying the "chlorophyll" or leaf green in those cells.

No. 2 shows the fungal threads at work. In a diseased potato plant these threads or "mycelial hyphae" as they are called, run through the substance of the leaves and pith, and down the haulm into the tubers from which they consume the food stored there.



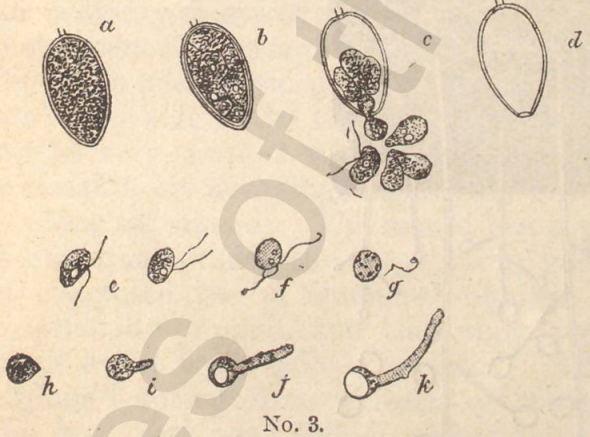
No. 2.

The manner in which the mycelium pervades the leaf is well shown in this illustration. The aerial hyphae (F) generally find their way out of the leaf on the under side, as this is supplied with almost innumerable small openings or breathing pores called "stomata," which admit air from which carbonic acid is extracted to assist in building up the plant. Not only do these openings afford easy egress to the hyphae, but the threads of mycelium (E) are able to form more readily near to the under side, the upper section being largely occupied by

structural cells (B) which, from their resemblance to palings, are called "palisade cells." The intermediate cells in which the mycelium is most plentifully found are the living cells—that is the cells which are actively engaged in assimilating the food taken into the plant through the roots and leaves, converting it into substances ready to form new parts of the plant. These cells are placed irregularly, and not close together, as the air is required to circulate round them. The juices of these cells are readily seized by the mycelium, and instead of going to the support of the plant, they go to maintain the fungus. When the leaves are destroyed, the plant can obtain no air internally, consequently no food is assimilated and it speedily dies. Following upon the destruction of the leaves the mycelium generally traverses the haulm until finally it reaches the tubers. Here it travels between the cell walls, expands the intercellular space, absorbs the contents of the cells, finally breaks them down and the tuber decays.

THE SPREAD OF DISEASE.

Fortunately for those interested in the subject, the manner in which the potato disease is carried from plant to plant has been satisfactorily proved. The "conidia" or spores are carried on the aerial hyphae or branches of the fungus growing outside the leaf. The branches are jointed somewhat like a bamboo cane, and a conidium is given off at each joint. These contain a thick liquid substance which, when the conidia ripen, and are placed in moisture, breaks up into several smaller spores called "zoospores," so extremely minute, that when 3,000 are laid side by side in a line they only reach an inch.



No. 3.

a. Ripe conidium in water.

b. Protoplasmic contents breaking up into blocks, which separate and escape.

c and *d*. As minute kidney-shaped zoospores.

e. Each provided with two cilia.

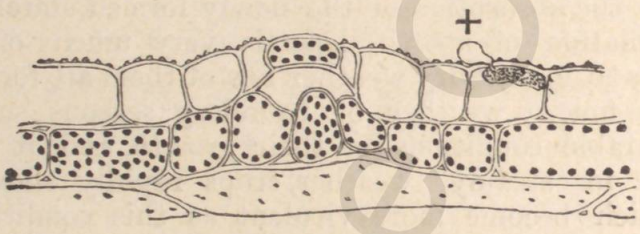
f and *g*. The zoospore coming to rest and losing its cilia.

h, *i*, *j*, and *k*. Successive stages of germination of the zoospore.

The zoospores soon emerge from the spore and each is quickly equipped with two fine hair-like tails or vibrating hairs (cilia). The zoospores are able to move in the slightest film of moisture, being propelled by the whipping motion of the cilia. After a brief time the little zoospores rest and assume a globular form, the vibrating hairs dissolving away or shrivelling into the finest dust. In a short time they burst and produce a thread of spawn, which is capable of carrying on the existence of the fungus. These tiny zoospores are easily transported on the air, or by birds, insects or other agencies, and alighting on a potato plant they thrust their thread-spawn into the leaf and establish themselves in the plant.

As bearing on the prevention of the disease by means of spraying with Bouille Bordelaise, the marvellous instinct these zoospores possess of recognising when they have found a suitable host on which to establish themselves is worthy of notice. If the germinating zoospore produces its spawn on any substance other than part of a potato, tomato, or other solanaceous plant, the thread does not attempt to pierce it, and the zoospore shortly dies. But if it falls on a potato plant (especially if on the leaf) the thread of spawn at once endeavours to force its way into the plant; and this it is the better enabled to do, because the tip of the thread is furnished with a substance of the nature of a ferment, possessing the power of dissolving its way through the outside of the leaf. Cover the leaf with a film of copper, hateful and hurtful to the thread of spawn, and the disease will not enter the plant.

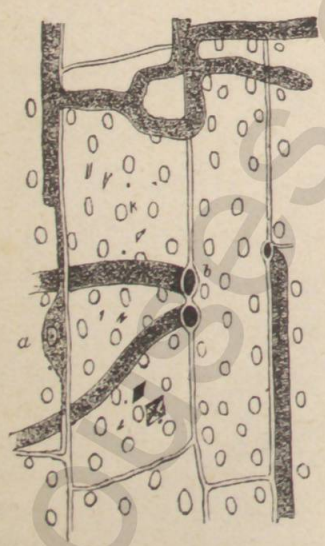
The stem is also liable to attack, for the zoospore can pierce through the skin and find its way to the cells. The protection afforded to the stem by the expansive upper foliage is sufficient to account for the fact that disease in the stem almost always follows, seldom precedes, disease in the leaves.



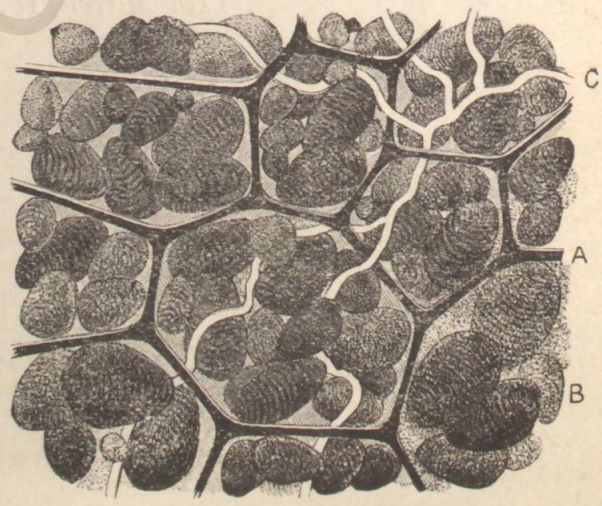
No. 4.

No. 4 represents a longitudinal section of Potato-stalk with germinating zoospore the germ-tube of which has pierced the cell-wall, and is growing inside the cell, as shown at +.

Another piece of tissue of the stem of a potato plant is represented in fig. 5. The hyphae of phytophthora is shown running in the cell walls; (*a*) the nucleus of a cell; the other contents are crystals and chlorophill corpuscles.



No. 5.



No. 6.

Fig. 6 is a section of a diseased tuber. A, the cell walls; B, the starch grains; C, the mycelial hyphae.

Deep moulding up of the potatoes prevents to some extent the disease attacking growing tubers. This is accounted for by the zoospore dying before it comes in contact with the tuber. A zoospore may germinate on the surface of the ground, but as it does not live many minutes, it may be dead before it is washed down to the tuber, should a considerable depth of soil intervene between the tubers and the surface.

When the zoospore has worked its way through the outer tissue of the leaf, it comes in contact with the living cells from which it at once commences to extract food, and it rapidly grows and spreads about the plant in the manner previously described. The living cells are all important to the plant, as in them the whole of the substance of the plant is manufactured, and as in a badly attacked plant all the matter which would go towards the building up of the tubers is arrested, this would be sufficient to render the crop unprofitable, but as decay is also set up, the plant withers and dies. In mild attacks when the weather is cool, or in varieties which from their special vigour are able to combat with the disease, the total destruction of the plant is not effected. Sometimes the disease does not spread to the tubers, but the yield is lessened by the absorption of the newly formed starch.

The formation of spores depends very much on climatic influences, and in cold dry weather few of them are formed. The mild moist muggy weather of thundery seasons supplies the most favourable conditions for their growth, and it is usually found that in "steamy" weather, crops rapidly show signs of disease which become more virulent as this condition of the atmosphere continues. It is found that the temperature most favourable to the development of the disease is 73 deg. Fahr.; above 78 deg. Fahr. no germinating takes place; below 50 deg. Fahr., there is practically no germination.

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