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SOME POTATO DISEASES
Their Cause and Control.

BY THE BOTANIST.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.
WYOMING
Agricultural Experiment Station.

UNIVERSITY OF WYOMING.

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Some Potato Diseases
Their Cause and Control

INTRODUCTION.

One hundred thousand dollars is an exceedingly low estimate of the loss to the state due to the partial failure of the potato crop in 1906. The probabilities are that five times that sum would come much nearer the actual amount. When we remember that in some parts of the state many of the fields were a total failure, a little calculation will readily show that the loss in the state represents so large an amount as to constitute a real set-back in its industrial development. So recently has Wyoming come to the front in an agricultural way that we have not yet become accustomed to thinking of the products of the soil as one of our great sources of wealth. The live stock industry, established in the old range days, probably yet overshadows all other enterprises in the state as a whole, but it seems safe to say that in certain sections the farm crops are of far greater importance than any of the other sources of income.

Experimentally it was proven, some years since now, that the soils of the state and the climatic conditions are admirably adapted to the production of potatoes, excellent in quality and not to be surpassed in quantity. It has, however, required years for the impression to take hold upon our citizens that potato growing on a commercial scale was profitable even beyond that of many other enterprises in which they might engage. In certain sections of the state farm communities have replaced the large stock ranches. The various farm
crôps have each come in for trial frequently enough to establish their relative worth. The result has been that potato growing has come into greater and greater favor, so that in late years this crop has been one of the most important.

It is, therefore, the more to be regretted that last year’s disastrous experiences should have come, not solely because of the loss incurred, but chiefly in that it has tended to check the development of a line of production for which our conditions are ideal. We are so accustomed to large results that failure or even partial failure and unprofitableness results at once in discouragement and a tendency to abandon that line for some other, even though the new line be in the nature of an experiment. We have not yet settled down to any fixed lines of effort in which determination to overcome all difficulties and to force success even out of our failures is a part of our life.

The time was when the causes of crop failures were considered inscrutable, and periodic losses were thought inevitable. Everything was attributed either to Providence or to weather conditions. Rusts, mildews, blights and the like were sent in punishment or were produced by wet, warm and muggy weather. It is really surprising how recently the real causes of the diseases that destroy our crops have become known even to those trained in the sciences which now form so important a part of our education. This is peculiarly true of the diseases which attack the potato. The present generation has seen the development of most of what we know concerning them. Even the last decade has witnessed the working out of those problems connected with the troubles which most affect us in Wyoming.

IGNORANCE OF CAUSES.

It is not strange then that the majority of the people are ignorant of the real causes which produce the failures that so often meet them. Especially are those in new communities
to be excused for lacking the information upon subjects concerning which little has there been thought and said. In the older communities, where the organizations established for the dissemination of just such knowledge have been actively at work, the facts as to causes and remedies have become more largely common property. It is so true in general that in new communities there is immunity for a time, that often those who understood the situation in the older communities become careless and indifferent. They are confident that no precautions are necessary under the more favorable conditions into which they have come. When they find that this is not the case, the better informed appeal for information, while the less informed are simply struck with the hopelessness of the case and are ready to give up that line of work entirely, or else merely struggle along with the thought that good and bad years must necessarily alternate.

There are enough unanswered problems yet, it is true, but there is no reason why some of the established facts should not become known of all, and the difficulties which are surmountable be pointed out. It is generally understood, though often in a hazy way, that many of the diseases to which the human body is subject are due to foreign organisms which live upon and within the system. It is less fully understood, especially by our farmers, that plant diseases are most of them caused in a similar way. The nature of the germs and the fungi by which the plants are attacked is not understood. It seems, therefore, justifiable to point out certain facts concerning them in order that the measures recommended for the prevention and eradication of diseases may be the more intelligently applied. No excuse is needed for supplying this information, nor is any reflection cast upon those who are not heretofore informed.

UNPREPAREDNESS.

Not only are our people unprepared as to information, but we are unprepared as to equipment for fighting the dis-
eases to which our crops are subject. Having assumed that nature is on our side, and that in this new land nothing is needed except the planting of the seed and the harvesting of the crop, we have been woefully deficient in methods of culture and in the means of protection. Spraying and its purposes are not understood; apparatus is not at hand; and the names of substances to be used have scarcely been heard.

PARASITES.

Indefinite and hazy as our notions may be in regard to plant parasites, if we will but compare them with animal parasites we shall acquire more definite ideas. Nearly everyone understands that most animals, including man, are more or less subject to attack or infestation by smaller forms of animal life. These parasites may live either internally or upon the exterior portion of the body. In any case, they feed either upon the tissues or upon the nutritive fluids of the animal attacked, which is then known as the host. In the course of time the host and the parasite come to sustain a very definite relationship to each other. The longer the parasite has maintained that relationship, usually the more completely dependent it becomes upon the host. Such parasitism has a tendency to produce degeneration in some of the organs of the parasite, and it may become not only dependent upon that kind of a life, but its dependence may be of such an intimate character that it cannot live upon any other host.

What is thus true of animal hosts and their parasites is often equally true of plants and their parasites. They sustain the same relationship, one supplying not only the food materials for itself, but also yielding up from its own tissues the substance upon which the other feeds. When one plant thus becomes dependent upon another for its food supply there is a tendency to lose from its organization all those structures which no longer serve any useful purpose. Thus certain plants are no longer green, having no further use for chlo-
roplasts. There are now many kinds which show this characteristic form of degeneration. Among these the most important, from an economic standpoint, is the great group which we call *Fungi*. There is no necessity for going into the question of the classification of this group further than to state that here belong the subdivisions which are now more or less well known as germs (*Bacteria*), rusts, smuts, mildews, blights, etc. These readily divide themselves into two principal groups, viz., (1) those which feed upon decomposing

*Fig. 1. A Normal Potato Plant.* Note the roots and the tuber-bearing stems and the position of each.
animal and vegetable substances and are known as *saprophytes*; 
(2) those which draw their nourishment from living plants 
and are known as *parasites*. It is this latter group with which 
we are concerned in this bulletin. What we want to keep in 
mind is that the parasite is as truly a plant as is the host upon 
which it lives; that the host is injured, not merely mechanically 
by the presence of the parasite, but is injured most of all by 
the substances which are drawn from it, and by the poisons 
which are secreted by the parasite and left within the tissues 
of its host.

**THE TROUBLES OF 1906.**

Almost without exception the relatively small crops or 
even total failures of 1906 are attributable to diseases caused 
by fungous parasites, as indicated in the foregoing discus-
sion. Among such diseases there are four that were prevalent 
and two that were unusually destructive. It is the purpose 
of this bulletin to discuss these diseases; the parasites that 
produced them, and the more recent and approved methods 
of combating them. This discussion will be based in part 
upon studies and observations made in the field during the 
growing season, but in large part it rests upon well-authen-
ticated knowledge which is the result of much research and 
experimentation on the part of various station workers in 
other states. It is difficult to give due credit to all who have 
helped to develop what is now common knowledge, but spe-
cial mention ought to be made of the persistent study which 
the subject of potato diseases has had at the Vermont, the 
New York, the North Dakota, the Ohio, the Colorado, and 
other experiment stations. So important is the subject that 
there is scarcely a state, in which potatoes are extensively 
grown, that has not published, for the benefit of its citizens, 
more or less of the information that has thus been accumu-
lated during the last decade.

That much may be done to make this information pec-
culiarly applicable to our Wyoming conditions, and that there
are for us still many problems to which we have only partial
answers, is true. For the solution of these, we must carry
out our own experiments, adapting them to the local condi-
tions of climate and soil. We cannot depend solely upon the
work and the results that have been secured in other states,
but must adapt those truths which seem to be universal to
the particular conditions under which our crops must be
grown.

POTATO INVESTIGATIONS AT THE WYOMING STATION.

Ever since this station was organized much interest has
been taken in all matters pertaining to potato growing, as
may be seen by referring to the files of the Wyoming bulletins.
The published information rests upon numerous carefully
planned and executed experiments, and has undoubtedly served
a useful purpose in bringing the industry to its present state
of development. Mention should especially be made of Bul-
letin No. 32, by Prof. B. C. Buffum. It contains exhaustive
discussions of a great many phases of potato raising. The
following subjects treated in it may be mentioned: Potatoes
on different soils and following different crops; Subsoiling;
Fertilizers; Insect enemies; Diseases; Methods of preparing
the seed potatoes; Whole versus cut seed, and methods of
cutting; Amount of seed per acre; Cost and profit of grow-
ing; Variety tests. In the experiments which led up to this
bulletin, Prof. Buffum's discoveries concerning the effect of
the treatment of the seed have been most favorably received.
Other publications from this station dealing with one or more
phases of potato problems are Bulletins Nos. 19, 22, 31 and
41; Press Bulletin No. 6; Tenth and Twelfth Annual Re-
ports.

STRUCTURE OF THE POTATO PLANT.

It will help to understand the discussion of the diseases
that follow if some mention is made of the structure of the
potato plant, especially of its leaves and the relation of these
to the formation of the tubers. Besides the general terms—root, stem and leaf—the application of which is clearly understood by everyone, attention should be called to the fact that the tuber (the potato, we ordinarily call it) is but a modified form of the stem itself. In our thinking we sometimes confuse the tubers with the roots of the plant, but a little examination will show that the true roots are numerous and relatively slender, and similar in all respects to the roots of other plants. The tubers, or potatoes, are not borne on these, but on somewhat thicker horizontal underground branches, or stalks, which become thickened and enlarged at the end or, more rarely, also at intermediate points (see the accompanying illustration, Fig. 1). By examining the way in which these tuber-bearing stalks arise, it will be seen that they are really branches of the main stem, usually arising from the joints, or nodes, sometimes some little distance above the point from which spring the true roots.

In order to understand the relation of the leaves to the tubers, it is necessary to know that the starches and other food materials, which are stored up in the tubers, are produced within the leaves through the activity of the contents of the leaf cells when influenced by the action of light. The leaves are green because the cells contain the green bodies technically known as chloroplasts. No plant which lacks chloroplasts is capable of manufacturing starch.

Leaf structure is essentially the same in all plants. A section from the upper to the under side will show on either side an epidermis of flattened, colorless cells (study the structure as shown in Fig. 2). The cells immediately underneath the upper layer are elongated and closely packed and are known as the palisade tissue. The lower half of the leaves contain nearly spherical cells, rather loosely arranged, with conspicuous air spaces near the lower epidermis. These communicate freely with the smaller spaces among the cells, and are continuous one with the other throughout the leaf. The
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Air spaces are in direct communication with the outside air through tiny openings known as stomata. These openings on the surface often occur on both sides of the leaf, but in most crop plants they are more numerous on the under side, or may be entirely wanting on the upper. They are very im-

Fig. 2. LEAF STRUCTURE. A diagramatic drawing representing the microscopic structure and showing the stomata on the under surface, through which fungi find entrance or protrude their spore-bearing branches. (From Vermont Report, 1890.)

portant to the plant, since it is through them that the plant food derived from the atmosphere finds ingress to the leaf, which is really the plant's starch-factory. They also serve the very important function of allowing the escape of the watery vapor and the oxygen which is released during the
period of active starch formation. Necessary as are these openings on the leaf surface, they are also sources of great danger to the plant. The rest of the surface of the leaf is so thickened or water-proofed with the substance known as cutine that water cannot enter nor escape through it, neither can germs from the atmosphere find entrance into the leaf. When germs or other fungi secure admission to the tissues of the plant it is usually either through the stomata or through wounds upon the leaf or other part of the plant. It is for this reason that insect attacks are so often followed by fungous and germ diseases. Similarly wounds which plants accidentally receive or which are made by pruning are also often followed by diseased conditions.

The crude sap of plants, which is essentially the soil water with the gases and soluble minerals of the soil dissolved in it, is taken up by the roots and conveyed through the stem to the leaves. The air which has been admitted to the leaf through the stomata supplies the carbon-dioxide. From these ingredients, through the agency of the protoplasm of the cell and the chloroplasts acting in the presence of sunlight, starch is manufactured. This starch is temporarily stored in the leaf, but at night, when starch formation no longer is going on, the starch is, through the action of a ferment, converted into soluble form and is transmitted from the leaf through the stem to the underground stems, which become gorged with the material thus received. Another ferment now reconverts this soluble form of starch into the insoluble, which is then deposited in the tuber as a permanent part of it. The ultimate size of the tubers, therefore, depends upon the amount of starch that is thus formed by the leaves and transmitted from time to time to the tubers for storage.

It seems that most of the crude sap passing upward in the stem is transmitted through ducts in the interior tissue, while the elaborated sap (as it is called when it has been acted upon by the leaf and is in condition to be used as plant
food) is conveyed downwards close to the exterior of the stem, viz., in the interior layers of the bark. It follows, therefore, that any injury to the inner bark or any artificial obstruction in these layers will prevent the downward movement of this \textit{elaborated} sap. In the case of the potato, an injury to the bark will prevent the formation of tubers, as the sap conveying the soluble starch can no longer reach them. In the event of the elaborated sap being left in the above ground portions, it results either in very marked increase in the size of leaf and stem, through forced feeding, or the plant will attempt the formation of tubers above ground. This, in fact, often happens in one of the diseases to be discussed (\textit{Rhizoctonia}), in which small tubers are frequently formed upon the lower portion of the stem or in the axils of the leaves.

\textbf{FIELD STUDY.}

It was the privilege of the writer to make an extensive and careful field study of the potatoes in Wyoming during July and August of 1906. Some observations were made in each of seven out of the thirteen counties.

One or more of the diseases discussed in this bulletin were found to be present to an unusual extent in each of the seven. Crop failure to a greater or lesser extent was evident even thus early in the season. Appeals for information and remedies were frequent, but it was already too late to arrest the prevailing epidemics.

In the northern counties Early Blight was the first to attract attention, but much of the loss attributed to it was due, not to the blight, but to \textit{Rhizoctonia}. The growers, unfamiliar with both diseases, could not fail to note the spotted and sickly yellowish-green leaves, and, therefore, naturally enough attributed the whole failure to whatever had caused this appearance. They had not noted that the underground parts of the stem were often blackened or sometimes soft and almost rotted off. When both of these diseases were present
in the same field the vines were small and the crop an entire failure.

In some of the central and southern counties Early Blight occurred only occasionally, but *Rhizoctonia* was rarely absent. The crop as a whole was usually poor and many fields were left undug. Many growers were quite unaware of the true condition of their fields until their attention was called to the situation. This was not to be wondered at, for in so many cases the form of *Rhizoctonia* was that which attacks the stems near the surface of the ground, merely destroying the bark at that point (see the figures of *Rhizoctonia*), thus preventing the elaborated sap from reaching the tubers. As already explained under the heading, "The Potato Plant," *Rhizoctonia*, when it goes no farther than this, results in an unusually luxuriant growth, the materials which should have formed the tubers being used in forcing the growth of the tops.

Scab, of course, occurred throughout the state, but was perhaps less prevalent than usual. This is attributable no doubt to the fact that the practice of treating the seed is becoming more general.

Whether Late Blight occurred cannot be stated with certainty. If so, it did not develop until after the writer had returned from his tour of inspection. That it did occur in September seems probable from reports that reached this office and which seemed to be borne out by specimens. Unfortunately the specimens were taken so long after the trouble occurred and were so long in transmission that no conclusive opinions could be formed from them.

**DISEASE RESISTANCE.**

Several experiment stations are at the present time doing much work with potatoes with a view to determine the relative susceptibility of the different varieties to disease. It has been clearly demonstrated that there is a marked difference in the resistance to attack that they offer. The problem, how-
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ever, is exceedingly complex, for the reason that a variety found resistant to one disease is not necessarily resistant to the other diseases. Neither does it follow absolutely that varieties the most resistant in one part of the country are also the most resistant in another. Then, too, there are so many other factors of importance in selecting varieties to be grown that one cannot select solely because of this one quality. One must have in mind productivity, quality, marketableness, time of maturity, etc., as well.

Fig. 3. EARLY BLIGHT. Characteristic appearance of badly blighted leaf. (From Farmer's Bulletin 91, U. S. Dept. of Agr.)
THE EARLY BLIGHT.

(Alternaria solani.)

HISTORY.

This disease has probably been long in existence. Our knowledge of it, however, is exceedingly recent. So long as the real nature of potato diseases were not understood, the different kinds of such diseases were not discriminated. They were all classed under one name, if named at all. Our first definite knowledge of the Early Blight was worked out in this country in the early '90's, though references to it occur somewhat earlier in the Nineteenth century in European literature. It had been overlooked or confounded with the Late Blight, but it is now fully understood that the parasitic organism causing it is wholly different from the one causing the Late Blight in structure, in method and time of development, as well as the conditions under which it occurs.

STRUCTURE.

The fungus, like most other plant parasites, lives within the tissues of the host, spreading its mycelium through the intercellular spaces of the leaf. It consists of slender threads (hyphae) more or less branched, which tend to become aggregated in certain areas, the tissues of which die, producing the characteristic brown spots. While in full growth and while the tissues of the host are supplying an abundance of food, there are few, if any, reproductive bodies (spores) produced. When the leaves become partially exhausted and dry, spore reproduction takes place freely and the characteristic several-celled spores, formed in chains, occur abundantly (see Fig. 3).

HOW RECOGNIZED.

Since the Early Blight has only recently attracted attention in this state, it is not generally known to our growers.
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It may, however, be readily recognized and easily distinguished from the Late Blight and the other potato diseases. Early Blight begins to show itself about the time that the blossoms appear, which, with us, is usually in July. More rarely it attacks plants scarcely six inches high. The first indications are relatively small grayish-brown spots, which, as they become larger, are marked with faint concentric circles, giving a target-like appearance to them. The spots may increase in size till several of them run together and form large patches of dead tissue. In the course of a few days these spots become brown and withered (see Fig. 3), while the rest of the leaf takes on a yellowish, sickly color, though the stems may remain green. Sometimes the disease progresses quite slowly and the vitality of the plant is only gradually reduced. In any case, however, the tubers either stop growing entirely or remain so small as to make them of little value. The death of the vines in this way is often mistaken for early ripening and it then occasions a surprise to find that no tubers of value are present.

Any injury to the foliage, such as insect bites or bruises from hail, seems to furnish the condition for the entrance of the fungus into the leaf. Likewise any decline in the vigor of the plant seems to invite attack. Drought, poor soil, delayed development due to cold weather, excessive heat tending towards wilting or sun-scald, all make the plants less able to withstand the attacks of this Blight. In other words, the more nearly perfect the plant and the more vigorous its growth the less likely it is to suffer from this parasite.

SOURCE OF INFECTION.

But little is known concerning the source of the disease. The tubers seem to be wholly free from attack, and there is, therefore, no reason for suspecting that the seed potatoes carry the disease over from one year to the next. Certain it is that somewhere the several-celled black spores winter over and start the disease again the following season. That this might
happen where the dead tops are not destroyed, but are scat-
tered about over the field and farm, is easily understood.

TREATMENT.

Satisfactory treatment for this disease has not yet been found. Many experiments, however, have shown that the effects of the disease may be greatly reduced by two or three thorough sprayings with Bordeaux mixture. The spraying must be thoroughly done and the first application must be made previous to the appearance of the Blight. After the leaves have become filled with the mycelium and the spots are beginning to show it is too late. Prevention must be the aim, and this is accomplished by putting the leaves in such a condition by the application of the Bordeaux that the spores cannot germinate upon the leaf surface. For further direc-
tions, see the subject of spraying at the close of this bulletin.

THE LATE BLIGHT.

(Phytophthora infestans.)

HISTORY.

Though this disease had not been fully worked out until in comparatively recent times, yet there are references in literature to potato epidemics which devastated the fields of Europe at intervals during the Nineteenth century, which were undoubtedly due to it. The first recognizable descrip-
tion occurs first in 1845. Its life history, however, has now been known for some time, though as late as the '80's and '90's this trouble was still confused with the Early Blight which has been discussed in the preceding pages. For a con-
siderable time it was not known that the rot which usually follows an attack is also due to the same parasite. While probably of rare occurrence in the Rocky Mountain states,
Late Blight is feared more than any other disease in the potato districts of the eastern states. It is estimated that the loss in New York alone sometimes amounts to $10,000,000 a year.

Fig. 4. LATE BLIGHT. The appearance of the leaf in the early stages of the disease. (From Vermont Report, 1892.)

**STRUCTURE.**

Though this fungus resembles the Early Blight in many respects, yet it is easily distinguished from it by its mode of growth, the effect it produces upon the leaf tissues, and especially by the spores and the way in which they are produced. It finds entrance into the potato leaf through the stomata (previously described), and the mycelium once hav-
ing found entrance spreads by numerous branching hyphae through the leaf among its cells from which the fungus draws its nourishment. After the leaf has become filled, as it were, with the mycelium, the fruiting period of the fungus is reached. Some of the hyphae then grow out through the stomata, branch, as shown in Fig. 6, and produce small pear-shaped bodies on the tips of the branches. These latter structures, known as sporangia, serve to spread the disease to other parts of the field. They are very readily detached from the filament upon which they are grown and then fall upon the soil or are carried far by the wind. If they happen to fall upon a potato leaf they will begin to grow just as soon as a little moisture either from rain or dew is present. This growth consists either in the formation and discharge upon the surface of the leaf of several free swimming spores, capable of infecting the plant, or in the direct formation of a filament which enters the leaf through a stoma and develops again a mycelium. From this mycelium other similar reproductive bodies are formed, in turn, to further infect the field.

HOW RECOGNIZED.

During the time that the fungus is spreading its mycelium through the tissues of the leaf there is little to indicate its presence. When the fruiting stage is reached it soon becomes evident enough by the formation of brown spots, which grow gradually larger and larger, finally turning black and a little later decomposing and emitting a disagreeable but characteristic odor. If one of these infested areas (see Fig. 4) be examined closely, it will be found to be bordered by a grayish-white mildew. This latter, under examination with a lens, is seen to be the branched fruiting hyphae bearing the sporangia described in the preceding paragraph.

For the development of the mycelium, that is, for the growth of the fungus within the potato plant, moderately cool weather seems the most favorable. For this reason this disease
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Fig. 5. **LATE BLIGHT.** The last stages of the disease. When this is reached the field looks as if fire had swept over it. (From the N. Y. Expt. Station, Geneva, Bull. 241.)
rarely proves troublesome where high temperatures prevail for considerable periods of time. Spore production, however, seems to be hastened and enormously increased when a few days of warm, cloudy and muggy weather alternate with the longer cooler periods. Under such conditions, a field showing but slight infection, may in a few days look as if it had been swept by fire or frost (see Fig. 5). It rarely attacks early potatoes, mostly appearing upon the late varieties during the tuber-forming period.

**TREATMENT.**

Various experiment station workers have tried different remedies for holding this disease in check. At some stations these experiments have been carried on for many years. While several have given results which were of value, no treatment has been so uniformly successful as the application of Bordeaux mixture. The universal experience is that spraying with this fluid will so nearly control the Late Blight as to make it possible to secure a crop even in those years when this disease is most prevalent. It requires, however, that the spraying should be begun in time and continued at intervals throughout the growing season. As already stated, it must be a precautionary measure. If not begun until after the Blight is evident in the field only partial control can be expected. If the spray is applied thoroughly from the beginning, not only will the Blight be controlled, but the rot of the crop which usually follows a severe attack is altogether prevented.

**POTATO ROT.**

It has been almost conclusively proven that the rot of the tuber which follows an attack of Late Blight is really due to the infection of the tuber by the spores which have fallen upon the soil and which, in the course of the season, are carried by rains or irrigation waters into contact with the tuber itself. Here it may begin growth at once or it may develop after the
Fig. 6. Late Blight. Illustrating leaf-structure, the microscopic structure of the fungus and its relation to the leaf. (From the Report, Dept. of Agr., for 1888.)
potato has been dug and stored. Sometimes a large portion
of the crop is thus lost even after it has been harvested. Thorough spraying of the vines will, at the same time, impregnate
the surface of the soil with the copper-sulphate solution. Thus
not only is the formation of any considerable number of spores
prevented, but the spores that do happen to reach the soil are
destroyed.

**SOURCE OF INFECTION.**

It is believed that the spores of the fungus do not live
through the winter. If that be true the mycelium of the
fungus must either live over in the dead tops that are left
strewn about the field, or else the tubers carry the disease
over from one season to the next. The latter is thought the
more probable, as it has been seen that the blighting of the
tops (if not checked by spraying) is very likely to be followed
by rot of the tubers, either before or after digging. Of
course no one would think of planting badly rotted potatoes,
but those that are but slightly affected may escape notice.
These, if planted, will be sufficient to start the infection the
next year, and once started it soon goes over the field.

**RHIZOCTONIA.**

*(Corticium vagum solani.)*

**HISTORY.**

It is more than probable that under this name are in-
cluded more than one distinct disease. At least a number of
forms of the disease occur, and if it be due to one parasite, it
is capable of attacking a number of host plants. The rasp-
berry, carnation, beet, lettuce and quite a number of others
have shown themselves susceptible to attacks of *Rhizoctonia.*
Whether these different forms of this disease are distinct from
each other has not yet been demonstrated. The disease as
Fig. 7. RHIZOCTONIA. The base of the stem is attacked, destroying the bark, and sclerotia are developed which perpetuate the fungus. (From Bull. 70, Colo. Expt. Station.)
it occurs on potatoes is known under several common names. Among them are "Stem Rot," "Rosette," "Little Potatoes," and what seems to be the same thing in Europe as "Black Foot." This, like the other diseases of the potato, has no doubt long existed, but has not been described in a recognizable way except during recent years. The occasional loss of our field crops was in former times supposed to be due to inexplicable causes and, therefore, inevitable.

**STRUCTURE.**

Though widely distributed throughout the United States, as well as in other parts of the world, it seems to be peculiarly prevalent and destructive in the middle west and in the Rocky Mountain states. Perhaps the most careful work upon it, as applicable to our locality, is that which has been done at the Colorado Station during the years 1901 to 1904, and since the form that the disease assumes in the mountain states seems to be much the same, we avail ourselves largely of this work. This fungus, unlike those already discussed, attacks the underground portions of the plant. It is a true parasite, living either in the internal tissues or upon the external parts. It attacks the stem at or just below the surface of the ground, destroying the bark in whole or in part. If the attack be a severe one it may result in the death of the plant, but if less severe it may induce a wet rot and thus result in the death of the plant, but if less severe it may simply girdle the stem (see Figs. 7, 8 and 9), the plant continuing to live and often producing as a result of the girdling an enlarged and apparently vigorous top. Owing to the fact that the girdling will prevent the return of the elaborated sap to the underground portions, there can be no tubers formed, or if formed they will be few and small. In many instances when the plant is thus prevented from forming the underground tubers, it will throw out from the stem at points above the injury many short tuber-forming stems (see Fig. 9). These
RHIZOCTONIA. When infected seed-potatoes are used the fungus advances from these into the young stems, which soon show the presence of the disease. (From Bull. 70, Colo. Expt. Station.)
tubers, of course, are always small and, being formed in the light, are of no value. If not thus clustered at the base, they may be formed in the axils of the leaves for some distance upward. This peculiar characteristic of attempting to store the starch above ground, which the disease prevents being stored underground, has given rise to the common name, "Little Potatoes" (see Fig. 9).

The tubers are also attacked by the fungus and on the surface of these are produced small hard knots of mycelium, which are technically known as Sclerotia. These appear as dark brown bodies, irregular in outline and varying from a mere speck to the size of a grain of wheat. When dry they are almost dirt-colored and are, therefore, not readily distinguished from the soil that may adhere to the tuber. If the potato be washed, however, the difference readily appears, since the Sclerotia adhere so firmly that they are not to be removed in that way.

Prof. F. M. Rolfs, in his exhaustive studies of this disease,* finds that there are three distinct stages in its development as it occurs here in the mountain states. These he designates:

(1) The Rhizoctonia Stage.—This may be considered the first or growing (vegetative) stage. Two kinds of hyphae occur—light-colored ones in the inner tissues of the host, which, if abundant, produce a wet rot; dark-colored ones in the outer tissues forming a close web or felted covering, which constitutes merely a girdle or band (see Figs. 7 and 8). If this last only is present the potato plant is not killed, but may in fact, as previously explained, seem unusually thrifty.

(2) The Corticium Stage.—It had been supposed that this fungus produced no spores, but was perpetuated solely by the sclerotia which are the closely compacted masses of the mycelium forming the dark scale-like or grain-like bodies on the tubers and stems of the host plants. Prof. Rolfs

*Bull. 91, Colo. Expt. Station.
Fig. 9. Rhizoctonia. "Little potatoes," the attempt of the plant to form tubers above the point of injury by the fungus. Note also the little tubers at the base of the branches. (From Bull. 70, Colo. Expt. Station.)
Wyoming Experiment Station.

finds, however, that at one period of its development minute spores are formed upon short lateral branches arising from the hyphae of the Rhizoctonia state. These spores are so easily dislodged that their presence is easily overlooked even when a microscopic examination is made. It is probable that the spores serve merely for the rapid dissemination of the disease during its vegetative period.

(3) The Sclerotium Stage.—This is the period in its development when provision is made for the perpetuation of the fungus. As described in the preceding paragraph, closely compacted masses of the mycelium form grain-like or scale-like bodies on the tubers and stems (see Fig. 10). These sclerotia, as they are called, carry the life of the fungus over to the next growing season.

SOURCE OF INFECTION.

The foregoing paragraph has indicated the way in which the fungus is preserved from year to year. The sclerotia found upon the tubers of an infected crop will start the growth of a new mycelium when such seed potatoes are used. This new mycelium follows up the new sprouts when the potato begins to grow, producing as before the characteristic infection of the young stem near the surface of the ground (see Figs. 7 and 8). Sclerotia are also carried over in the field upon the stems of last year’s crop and probably also upon the stems of certain weeds.

TREATMENT.

The foregoing facts as to the manner of infection indicates the method of preventing this disease. Clean seed in clean soil will produce a clean crop. This means, do not plant potatoes this year in the same field where Rhizoctonia occurred last year. In other words, rotate your crops: It means, too, do not use seed potatoes that are infected, that is, that came from a field in which the disease existed. If you can get no
used on one of the plots (From Bull. 70, Colo. Exp. Sta.)

The upper figures show the increased yield upon similar plots of ground due to treating the seed one season the next. These carry the fungus over from

11. 10. Kneecocka. The lower figures show the sclerotia upon the tubers.
other kind, then select those which show no sclerotia. Remember, however, that the sclerotia may be so small or so scattering as to be easily overlooked. In all cases where there is the slightest suspicion of the seed, treat it. The object of this is the same as in the treatment for Scab—to kill the fungus without killing the seed. Since the treatment for Scab has been found the most effective for Rhizoctonia also, for the method of treatment see that topic under Scab.

POTATO SCAB.

(Oospora scabies.)

This fungus disease is too well known to need any description. All who use as well as those who grow potatoes know the familiar, irregular, sore-like blotches which sometimes are so numerous as nearly to cover the whole potato. Only the surface may be affected or the fungus may have penetrated and broken down the tissues almost to the center. While probably not wholly preventable, yet it is the potato disease that is the most readily held in check. With clean or properly disinfected seed, if one puts it into clean ground (free from the fungus), the crop should and will be essentially clean. It is well known that once the fungus gets into the soil it will live over winter and infect the next crop more completely than the former. Just how many years may be necessary to completely rid the soil of the fungus is not definitely known, but it is certain that another crop of potatoes should not follow scabby potatoes for two or three years and probably better not for four or five. Other crops on this land are not attacked, which points anew the safety and desirability of a scheme of crop rotation extending over several years.

Having decided upon the variety to be planted, and this choice must rest upon many characteristics, such as quality,
shape, period of ripening, resistance to disease, marketable-
ness, etc., then select those that are the freest from scab of any
that you can find. It is well to remember that the absence of
the characteristic surface markings is not conclusive evidence
that the potatoes are free from the fungus. They may have
been in contact in the bin with scabby specimens, as a result
of which they are infected abundantly with the scab spores.
Unless you are sure of the condition of the seed, it will pay
as a precautionary measure to treat (disinfect) the seed.

The old method is quite largely in use in the state and
must still be regarded with much favor. The new method,
however, has some very practical advantages. Both are given
below, so that if the ingredients for one is not at hand the
other may be used.

*Fig. II. POTATO SCAB. This shows the characteristic appearance
of potatoes badly attacked by the scab fungus. (From Farmer's Bul-
letin 91, U. S. Department of Agriculture.)*

**CORROSIVE SUBLIMATE TREATMENT.**

Dissolve two ounces of corrosive sublimate (*Bichloride
of Mercury*) in two gallons of hot water. When the corrosive
sublimate is dissolved, add cold water till you have fourteen
gallons in all. Having put the potatoes in a gunny sack, place
the sack in the solution and leave it there for one and a half hours. Then empty the potatoes out upon a floor to dry before cutting and planting. If they can be left thus exposed to the light and air for a few days they will grow all the better.

**CAUTION.**—If taken internally corrosive sublimate is a violent poison, hence all animals must be kept away from the solution and the treated seed. On account of its action on metals the solution must be prepared in wooden vessels, a barrel, for instance. See that the potatoes are clean. Put them into a coarse gunny sack and place it in the solution. The vessels and all objects in contact with this poisonous solution must be destroyed or thoroughly cleaned.

**FORMALINE TREATMENT.**

Formaline (or Formaldehyde) may now be secured at moderate cost at any drug store, or can be secured from the larger drug firms (by express) at fifty cents (or less) per pound. Since this treatment is at least as effective as the other, most people will prefer to use it for the following reasons: (1) It is easily prepared; (2) any kind of vessel may be used; (3) it is not poisonous to handle.

**METHOD.**—Soak the seed potatoes for two hours in a solution of 15 gallons of water and one-half pint (half pound) of Formalin. Smaller or larger quantities in the same proportion. Dry the soaked seed, cut and plant as usual.

It is well to remember that disinfected seed will be re-infected if it is put back into the dirty sacks or boxes from which it was taken. If to be used again, disinfect the sacks and boxes also.
SPRAYING.

Since Rhizoctonia and Scab must be controlled by rotation of crops and by the disinfection of the seed, the subject of spraying must be considered in connection with the Early and the Late Blight. Both of these it has been shown may be held in check by spraying with Bordeaux Mixture. Spraying is in the nature of insurance, for it must be begun before you know whether blight is going to develop. It is with blight as with fire—if you wait till you see the blight or the fire, you can't get your insurance. Naturally, then, the question is,

DOES IT PAY TO SPRAY?

On this point we have but little experimental evidence in the Rocky Mountain states. We can, however, draw some inferences from the reported experiences elsewhere. In many of the eastern states they have piled experiment upon experiment, and as the experiments have increased in number the more emphatic has been the conclusion IT DOES PAY.

Without going into detail as to the experiments conducted and the results obtained at the Vermont, the New York, the Ohio and several other experiment stations, it may be said that the evidence in favor of spraying is overwhelming. For instance, the average increase in yield in the Vermont Station for thirteen consecutive years was 115 bushels per acre. Other stations report results almost as remarkable.

WHY IT PAYS.

Spraying pays enormously during the years when blight appears, because those years "no spraying no crop." It has been shown that it pays other years also because of increased crops. This increased yield is to be attributed (1) to the increase in vigor of the sprayed field and the longer period during which the plants will continue in full growth; (2) to
the freedom from the potato beetle, the flea beetle and other insects.

COST OF SPRAYING.

The cost of spraying varies from $3.00 to $6.00 per acre, per season, depending upon the cost of labor and materials, the number of sprayings, and the original cost of the necessary apparatus. In Wyoming the Late Blight is probably of rare occurrence, but the Early Blight must probably be fought frequently. In the effort to control this there seems to be no material gain in spraying more than three times. The first applications should be when the plants are six to eight inches high; the next two applications at intervals of ten to fourteen days. Should Late Blight threaten, continue at similar intervals till five applications have been made.

INSECTS.

The best method of holding insects in control is by spraying. The spray to use is the Bordeaux mixture, to which has been added Paris green at the rate of one to two pounds to every fifty gallons of the Bordeaux. Using the Paris green in Bordeaux is more effective than by itself, since the Bordeaux is also distasteful to insects. If Paris green is used without the Bordeaux it should be dissolved in water at the rate of one pound to fifty gallons of water, applying from 100 to 200 gallons of the mixture to the acre. Some prefer to add to each 50 gallons of the solution two to four pounds of lime slacked as for whitewash. It is thought that the lime prevents the burning of the foliage by the Paris green. It is generally conceded, however, that the use of Bordeaux and Paris green together makes both more effective.

A SPRAYING SUGGESTION.

Few people find it economical to own their own threshing machine. It saves time, money and annoyance to hire some-
one who makes threshing a business. So in a community
where potatoes are grown by several people on a commercial
scale, it has been found practicable and satisfactory for some-
one to engage in spraying as a business. In that case he can
give enough time and thought to the matter to learn the best
methods, and can afford to invest in first-class power apparatus
which will enable him to cover large areas promptly. Then,
too, he can get the best materials at the lowest prices by buying
in quantity.

Of course, if there be only garden plots to be cared for,
each individual grower, or at most a very few together, will
require his own spray pump of a size adapted to his particular
needs.

BORDEAUX FORMULA.

Bordeaux mixture is made in several ways and in various
strengths, but in order not to complicate the matter only the
standard solution as now generally applied to potatoes will be
given. Some of the hardy plants, shrubs and trees will endure
this strength, but for tender varieties it is better to use a larger
quantity of water, and lime proportionately:

Copper sulphate ..................... 5 lbs.
Lime .............................. 5 lbs.
Water to make...................... 45 gal.

Method of Mixing.—In making up the Bordeaux mixture
in small quantities the following brief directions may be ser-
viceable: Secure two wooden pails, tubs or barrels, according
to the quantity that it may be desirable to prepare. One of
these vessels is used for the copper sulphate (blue stone) solu-
tion and the other for the lime. In dissolving the blue stone,
place it in a porous bag and suspend it near the surface of the
water in which it is to be dissolved. Slack the lime, using
only the amount of water necessary to keep it covered. Hav-
ing dissolved the blue stone and slackened the lime, dilute each
to twenty gallons and then pour the copper sulphate into the lime solution, stirring vigorously all the while, so as to combine the two. This solution may then be further diluted to make up forty-five gallons. In making up smaller quantities one would, of course, use the ingredients in the same relative proportion. The method just described is only one of the many ways that has been used in preparing this almost indispensable fungicide.

If one is going to prepare this solution on a large scale, or if one is going into the business of spraying for others, it is well to secure as much information as possible. There are many ways in which time and labor in preparation and handling may be saved. Among the many excellent publications treating more fully of these subjects the following may be mentioned:

No. 72, Vermont Station, Burlington, Vt.
No. 241, New York Station, Geneva, N. Y.
No. 272, New York Station, Geneva, N. Y.

SPRAYING APPARATUS.

Space will not be taken here to discuss at length the different kinds of pumps used in applying the solutions. The choice of a pump will depend upon the use to which it is to be put. For limited use one would naturally select a smaller pump than if a large field were to be covered. For house and garden plants a hand pump would be chosen, but for field crops on a large scale a power pump would be a necessity.

It is suggested that the purchaser would do well to secure descriptive catalogues from several of the many firms manufacturing pumps, and from these it would be possible
to select advisedly one suitable to each individual need. Among the firms advertising this kind of apparatus may be mentioned:

The Deming Co., Salem, Ohio.
Gould’s Manufacturing Co., Seneca Falls, N. Y.
Field Force-Pump Co., Elmira, N. Y.
Wallace Machinery Co., Champaign, Ill.
Cushman Power Sprayer Co., Lincoln, Neb.
Dayton Supply Co., Dayton, Ohio.
International Harvester Co., Denver, Colo.
Fairbanks-Morse Co., Denver, Colo.
William Stahl, Quincy, Ill.
Bean Spray Pump Co., San Jose, Cal.

It may be well to remind purchasers that a pump may be so cheap as to be worthless. As in the preparation of the spraying solutions it is highly profitable to use the best ingredients which can be obtained, so in selecting a pump it is profitable to pay enough to secure the one which will distribute the solutions most effectively. The Vermorel nozzle is usually used in potato spraying, and is supplied by most firms dealing in spraying apparatus.