THESIS

On

RHIZOCTONIA OF THE POTATO

Submitted to the

OREGON AGRICULTURAL COLLEGE

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In

THE SCHOOL OF AGRICULTURE

By

Jesse Harrison Corsaut

1915.
APPROVED:

Professor of Botany & Plant Pathology in Charge of Major

Head of Department of Botany and Plant Pathology.

Dean of School of Agriculture.

Chairman, Committee on Graduate Students and Advanced Degrees.
STUDIES UPON RHIZOCTONIA OF THE POTATO.

I. Introduction.

II. Historical.
   1. European.
   2. America.

III. Economic Importance.

IV. Laboratory and Field Studies.
   1. Life history of the parasite.
   2. General morphological characters of the fungus.
   3. Cultural characters of the different strains of the fungus.
   4. Relation of the parasite to the host plant and its tissues.
      a. Infection.
      b. Invasion of tissues.
      c. Resulting effects on the host plant.
         a' Direct
         b' Indirect.
   5. Comparative virulence of different strains of Rhizoctonia.
   6. Varietal resistance of potatoes to the disease.
   7. Control.
      1. Resistant vars. and seed treatment.
   8. Summary.
INTRODUCTION.

The potato is now one of the important crops of Oregon and will undoubtedly become even more important. There seem to be few staple crops, however, in which the yields are so uncertain. This uncertainty of yield is brought about by various causes among which fungous diseases are perhaps the most important. Among those fungi which are known to attack the potato, the plant parasite known as Rhizoctonia is found in practically every section where potatoes are extensively grown. The importance of the Rhizoctonia disease of the potato in the Pacific Northwest has been known for some time; but since no entirely satisfactory methods of control, or a complete knowledge of the nature of its attack, of its life history, or of its secondary effects upon the host plant have been worked out, a study of the causal fungus was undertaken by the writer in the fall of 1913 with the object of gaining a better understanding of these points. Due to the limited length of time for study much had to necessarily be left undone. It is hoped, however, that a start has been made in certain directions which will be of some aid to future workers on this subject.
STUDIES UPON THE RHIZOCTONIA DISEASE OF POTATOES.

History of Rhizoctonia Diseases in Europe.

The first reference made to the common fungus Rhizoctonia solani Kuhn, was that by H. L. Duhamel (21) a Frenchman in the year 1728. At that time his attention was called to a serious disease of Crocus sativus which upon investigation revealed the presence of a fungus made up of tubercules and hyphae. Not knowing its true nature he thought the sclerotia formed the fungus plant proper and the hyphae its root system. Fifty-four years later (1782) Bombacory described a Rhizoctonia sp. which was the cause of a disease of asparagus. P. Balliard (5), another French investigator gave the fungus a place among the classified fungi for the first time in the year (1791). He included it among the Truffles and called it Tuber parasiticum. Later in (1801) Persoon, G. H., (82) placed it in the genus Sclerotium and named it Sclerotium crocorum. De Candolle (22) in (1815) was the first mycologist to consider Rhizoctonia sufficiently different from other fungi to establish a separate genus. He discovered a Rhizoctonia sp. parasitic on lucerne and after studying several forms named three species, R. medicagnis, R. crocorum, and R. mali.

A few years later (1830) J. E. Duby (23) named a new species R. allii occurring on Allium ascalonicum and in 1843 J. H. Leveille (73) described a Rhizoctonia attacking Rubia tinctorum, Solanum tuberosum, Phaseolus and a species of Tulipa.

In 1851 the Tulasne (126) brothers united the various described
Rhizoctonia species into one species (probably composite) which they called Rhizoctonia violaceae. Shortly afterwards in 1885, Kuhn described three species occurring in Germany which he called R. solani, R. medicagnis, and R. crocorum. He distinguished between R. solani and R. medicagnis by the fact that the latter had woolly sclerotia while the sclerotia of the former were smooth. This was the first published report of the occurrence of the disease in Germany, although Kuhn mentions that he had noted the disease on sugar beets in 1858 and on carrots in 1854.

Following the report of the disease in Germany, reports of its occurrence appeared rapidly throughout Europe. It has been reported from all sections on various herbaceous, woody and fleshy rooted plants. At the present time and for the past twenty years the common European Rhizoctonia violacea has attracted considerable attention on account of its serious attacks on sugar-beets. A. Stift (119) has recently (1913) published a history of the beet rot caused by R. violacea in which he gives a chronological summary of the studies up until (1913).

Eriksson, J. (35) has recently carried on considerable cross inoculation work and has definitely proven that biologic forms exist. In his summary of the history of R. violacea in Europe published in (1913) he gives a clear-cut concise review of the studies up until that time. In this article it is of interest to note that the following statement is made: "It is doubtful as to whether the Rhizoctonia forms described by Duggar and Stewart of America are one and the same as the common R. violacea of Europe." Gussow (50) of England, however, considers R. solani and R. violacea identical.
History of Rhizoctonia Diseases in America.

The first report of Rhizoctonia causing a disease in America was in the year 1891. At that time Pammel (83) in a publication from the Iowa Station, reported a rot of beets due to what he considered to be Rhizoctonia betae. In the same year immediately following Pammel's report, Atkinson (2) reported (a) Rhizoctonia sp. as the cause of "sore shin" or damping-off of cotton seedlings in Alabama. In 1899 Duggar (27) reported Rhizoctonia as the cause of a beet rot in New York and also as the main factor in the damping off of beet, lettuce, bean, cucumber, and many other seedlings. He also attributes a crown rot of radish to the same fungus. In 1905 Atkinson reported a serious damping off of various seedlings under glass at Ithaca, New York to be due to the attack of Rhizoctonia sp. Probably the most important work to appear up to this time was that of B. M. Duggar and F. C. Stewart (29) in 1901, who list some thirty species of cultivated plants, including several plants of considerable economic importance, as being susceptible to the attacks of Rhizoctonia. The authors regard the fungus as being generally distributed and mention the possibility of its attack on plants in general provided the conditions; such as, temperatures, soil and moisture are proper for its best development. They include Solanum tuberosum among the plants subject to attack, and consider the disease produced on this host identical with a potato disease common in Europe, especially in Germany where it is known as "Grind and Pockenkrankheit." The European Rhizoctonia, however, was known to cause an ulceration and rotting of the tubers which the authors
were sure did not accompany the attacks of the fungus in this country.

Rolfs (103-4-5) of the Colorado Station in 1902 demonstrated beyond doubt that Rhizoctonia caused a serious disease of Solanum tuberosum under certain conditions.

Due to the fact that Rolfs was working under exceptional conditions many plant pathologists concluded that the disease was serious only under similar peculiar conditions. In his report Rolfs noted that one or more characteristic symptoms usually developed in cases where the attack was severe. An apparent thriftiness of the vines with the formation, however, of but few tubers was a condition commonly found. The formation of a large number of small worthless tubers near the surface of the ground was also of frequent occurrence. To this condition he applied the phrase, "Little potato disease."

He reported further that aerial tuber formation was quite common, this condition resulting from the destruction of underground parts of the plant. He also noted that many sprouts were blighted back before reaching the surface of the soil and that a deep ulceration of the aerial tubers was often present. Perhaps the most important contribution made in this publication is the report of the discovery of the perfect or basidial stage of the fungus, which was placed in the genus Corticium. He was able to develop this stage in the greenhouse. Pure cultures obtained from spores agreed with those obtained from the vegetative phase of the fungus.

Selby (121) in 1903 published results very similar to those of Rolfs. He noted in particular the excessive and conspicuous clustering of the leaves and branches. To this condition he applied
the term "Potato Rosette."

F. C. Stewart (111) in 1907 stated, that in spite of the similarity of R. solani of our country with that which causes a rot of tubers in Europe he is quite sure that the Rhizoctonia in this country does not cause a rot of the tuber.

Orton (80) (1909) in a U. S. department of Agriculture bulletin points out the seriousness of the disease in the San Joaquin and Sacramento Valleys of California. He estimated the loss in that section, due to the blighting of the stems and russetting of tubers to exceed $1,000,000 for that year.

Bailey (133) (1911) reports Rhizoctonia as being quite prevalent in certain sections of Oregon, a loss of 30% resulting in certain cases.

Gussow (134) (1912) gives a summary of the important characteristics of the disease as it occurs in Canada. Experiments carried on at the Canada station showed the superiority of corrosive sublimate over formalin seed treatment for this disease. Corrosive sublimate one-half the usual strength (1-1000) proved far more efficient than formalin.

Gloyer (52) (1913) carried on extensive experiments at the New York Station comparing formaldehyde solution, formaldehyde gas, and corrosive sublimate as to their effectiveness for use in seed treatment. His experiments proved corrosive sublimate to be thoroughly efficient while formaldehyde gas and formaldehyde solution were less effective.

Morse and Shapovalow (135) (1914) in a general report, state that beyond doubt, Rhizoctonia causes much greater damage in the New England states than has been reported in the past. A cracking
and ulceration of the tubers was commonly found associated with the attacks of the fungus.

Drayton, F. L. (1915) of the Canadian Department of Agriculture recently (1915), by careful histological examination proved beyond doubt that Rhizoctonia is parasitic and was the chief factor in the formation of the common lesions on the stems. Sections through the stems in a cankered region showed the presence of the fungal hyphae and inter and intra-cellular sclerotia in all parts of the stem.
ECONOMIC IMPORTANCE.

In Bulletin 186 of the Geneva Station reference is made to a potato trouble, reported by F. A. Serrine of the Iowa Station in the year 1890. Undoubtedly, as suggested by Duggar and Stewart, the investigator was dealing with a Rhizoctonia sp., although he was unable to identify the fungus at that time. This is the first account of the occurrence of Rhizoctonia as a potato disease in America. In a brief review of the investigation, as reported by Mr. Serrine (136), mention is made of a root disease, but the greater part of the report deals with an insect trouble. It is impossible to know the extent of the damage done at that time as no thorough investigation of the disease was attempted.

B. M. Duggar and F. C. Stewart (29) in 1901 were the first investigators in this country to make a study of the trouble as a potato disease. They mention the fact that the fungus was quite prevalent in different sections of the country, the disease having been discovered in New York, Pennsylvania, Alabama, Colorado, Iowa, Maryland, Michigan, and Ohio. The authors made no attempt at that time to determine the amount of damage done but were sure that the fungus was parasitic and caused some damage under certain conditions.

Rolfs (103-4) of Colorado was the first investigator in this country to call the attention of the public to the seriousness of the disease. In 1902 his investigations proved conclusively that a poor stand resulted in many instances from a serious blighting back of the young shoots. Following the attack at this stage of plant
growth, severe injury usually resulted to the subterranean parts of
the more mature plants, resulting in an abnormal top development
and the production of a large number of small worthless tubers at
the base of the stem. He also attributed the greater part of the
potato scab and ulceration to the attacks of Rhizoctonia.

In order to determine more accurately the amount of injury re­
sulting from the attacks of this fungus, a plot was planted with badly
infested seed and data kept as to the amount of damage resulting.
He noted a loss of 32% of the plants before they reached the surface
of the ground: 17% of the plants that made a growth failed to pro­
duce marketable tubers and in many cases the tubers produced were
scabby and of an inferior quality.

Selby (121) was making similar studies at this time in Ohio.
He noted particularly the abnormal top development and believed it
to be due to the injury of the subterranean parts of the plant.
This trouble he called "Potato Rosette." Selby estimated that in
many cases from 5-40% of the plants were effected in this manner.

While the rosette formation and various other symptoms of the
disease are secondary results of the parasiticism of the fungus,
they nevertheless indicate abnormalities which invariably result in
the reduced vigor of the plant and a small yield of worthless tubers.
Morse and Shaporalow (135) in a recent publication of the Maine
Experiment Station make the following statement; "In many sections
of Maine complaints have recently been received regarding poor
and uneven stands, unexpected low yields, sometimes associated with
early ripening or death of the tops from no apparent cause but re­
sembling an abnormally early maturity." The authors state that these
various troubles may be attributed to various causes but they are of
the opinion that Rhizoctonia is a factor and often a very important factor contributing to certain of the previously mentioned conditions.

Hume (58) of the Florida Station states that in certain parts of Florida from one-fourth to one-third of the plants were blighted back before they reached the surface of the ground. He is quite sure that Rhizoctonia has been one of the chief causes of poor stands in that section of the country.

Shear (120) estimated that a loss of 25% of the crop occurred in the San Joaquin and Sacramento Valleys of California in the year 1913. In the Delta region he placed the loss due to this parasite at close to $1,000,000. The greater part of this loss resulted from the girdling of the stems and the improper setting of the tubers due to the destruction of the rhizomes. Such losses as have been previously noted in various parts of the country have occurred to a certain extent in the Pacific Northwest. Rhizoctonia undoubtedly causes as much annual loss in this section as any other one trouble. Personal observation of some of the fields showed conclusively that poor stands and small yields were resulting in many cases from the attacks of Rhizoctonia. As has generally been the case elsewhere the occurrence of the trouble is many times attributed to various insect pests or rodents, or to poor seed, unfavorable weather and soil conditions, etc. Losses do, unquestionably, result as we know from these various causes, but Rhizoctonia is far more often responsible for the potato losses than is usually supposed. Failure to recognize it as the true cause of the troubles is due to the fact that practically all of the damage is done to the underground parts and that if these are examined the fungus will pass unnoticed.
except upon close observation at the proper time.

Several growers in the vicinity of Portland stated that great trouble was experienced in obtaining a proper stand. An examination of their fields left no doubt as to the principal cause of their trouble. Many of the sprouts which had come through were badly cankered and many others had never reached the surface of the ground. Some blackleg and insect injury was also noted but these troubles were secondary to the Rhizoctonia injury. An examination of a field near Troutdale in which the vines were almost mature showed the presence of the fungus in most every hill and no difficulty was experienced on a warm sunshiny afternoon in locating the badly effected plants on account of their slightly wilted condition and lack of proper color. These plants on close examination showed badly cankered stems and a much reduced root system.
Life History Studies.

Since the discovery of the perfect stage of Rhizoctonia sp. by Rolfs (104), no systematic study has been attempted to determine whether or not the perfect stages of the different described species of Rhizoctonia are identical. Several different fruiting forms have been suggested as the perfect stages of Rhizoctonia but in practically all such cases lack of close study has been such as to warrant no definite conclusions. Shaw (118) makes the following statement in regard to this phase of the subject: "It is quite probable that the form genus Rhizoctonia represents the vegetative stages of widely separate fungi and there may be some foundation in the observations of different fruiting stages, as reported by various investigators. Gussow (49) who considers R. solani and R. violacea as identical is of the opinion that corticium vagum represents their perfect stage. Eriksson (35) in referring to the fruiting stage of Rhizoctonia violacea makes the following statement, "At one time it was surmised to belong to Trichosphaeria circinans (Trematosphaeria C., Leptosphaeria C.), at another time to corticium vagum, and again to a species of the genus Rosellinia." Shaw (118) describes as Corticium vagum, the perfect stage of a Rhizoctonia which he considered to be Rhizoctonia violacea and which he believed to be identical with the Rhizoctonia described by Rolfs as Rhizoctonia solani. Shaw also described a Rhizoctonia which he considered to be Rhizoctonia solani but was not able to find its perfect stage. He considered this as possible evidence that the two forms were entirely separate
and suggested the possibility of their fruiting stages being in widely separate genera. If we are to accept Kuhn's original description of R. solani, then it would appear that Shaw was correct in concluding that corticum vagum represented the perfect stage of a Rhizoctonia sp. other than R. solani.

In the present study marked variation has been shown in the character of growth of the various strains of Rhizoctonia isolated from potato. If we were to consider only the variations of the sclerotia described by Kuhn as distinguishing characters in the separation of R. medicaginis and R. solani, then it would appear that we have both species. But as no authentic cultures of the various species could be obtained, and since the entire problem of a true classification of the members of the genus Rhizoctonia is still unsolved no definite conclusions can be drawn. The perfect stage of a species of Rhizoctonia has been commonly observed in various parts of Oregon during the months of June and July. This fertile stage consists largely of a delicate grayish white layer of fungal hyphae closely adhering around the base of the stem. If conditions are favorable the layer may extend up the stem for a distance of 6-8 inches and sometimes cover over the petioles forming a layer on the under surface of the lower leaves. Low, damp soil well protected from wind and air currents, warm moist air and a luxuriant growth of vines generally favors its development. This fruiting layer consists largely of interwoven closely septate hyphae which support upright basidia which in turn bear from 2-6 spores on long finger-like sterigmata. The spores are elliptical to elongate in outline and almost hyaline 9-15-6-13 . Plate I. Figs. 1-7 illustrate clearly the general character of the basidium, its
relation to the hyphal layer, the manner in which the spores are borne and their general form.

Experiments were undertaken to prove that this fruiting layer was associated with the vegetative phase of a Rhizoctonia species. Two methods were employed in obtaining pure cultures from single spores. First suspending a stem containing the spores over a suitable medium and allowing the spores to fall on the medium. Second by picking single spores and transferring them to a sterile medium. The first method is the one successfully used by Rolfs and was found to be the more satisfactory of the two.

Some difficulty was experienced at the outset in obtaining pure cultures on account of a lack of proper conditions for germination and contaminations of a Mucor sp. and Penicillium. These difficulties were later overcome by working in a special culture chamber, planting the spores in a medium containing an abundance of moisture and then placing them in an incubator at the proper temperature. Better germination was secured at a temperature of about 90°F. than at room temperature varying from 40-70°F. Pure cultures were obtained from fifteen different individual spores and in all cases these cultures presented the general characteristics of the cultures obtained from the vegetative parts of the Rhizoctonia fungus at a time when no spores were being produced.

In order to show more clearly the relationship between the different stages of Rhizoctonia, tubers which had been sterilized by treating in corrosive sublimate 1-1000 for two hours and planted in sterile soil were inoculated with pure cultures of Rhizoctonia which had been isolated from, the following stages. Sclerotia from
surface of the tubers, mycelium, spores and basidial layer. The plants were grown in six inch pots and kept separate in an especially constructed chamber. The rich leaf mold in which the plants were grown was kept moist at all times by the addition of luke warm water. Very little ventilation was afforded the plants and a temperature of close to 80° F. was maintained. Partial darkness was maintained by covering the hood with black paper. Under such conditions the perfect stage was formed on the newly developing shoots in 12-16 days after inoculation.

The characteristic corticiun layer was developed from all the plants inoculated with the strains mentioned above. Reisolations from the basidial layer of these different stages resulted in every case in characteristic Rhizoctonia growths. Table No. 4 gives in a concise form the strains used in this test and general characters noted in the study.
General Morphological Characters of the Fungus.

All the members of the form genus Rhizoctonia can quite readily be distinguished from other fungi by certain prominent characteristics of the mycelium. If grown under average cultural conditions on agar media extensive branching takes place producing a luxuriant white cottony growth. The mycelium at this stage is very sensitive to light and requires a very moist atmosphere for proper growth. The general form of the mycelial cells and the general character of growth are quite variable under different conditions. An abundance of moisture is very essential for a rapid, luxuriant growth. When such a rapid growth takes place sclerotia are not formed so soon. Under the same cultural conditions, marked differences have appeared between the different strains of Rhizoctonia used in the present study.

In case a very rapid growth has taken place the cells become more elongate, fewer septa are formed and less branching takes place. Under average cultural conditions on agar media the young branches are divergent in the direction of the growth of the parent branch at a more or less acute angle. The former are usually constricted where united with the latter and septa are invariably formed a few microns from the parent branch. All young growing hyphae are quite hyaline and contain little or no granular contents. Later on granular food material is formed and the cells take on a deeper color appearing brown in mass.
Sclerotia consisting of short barrel-shaped cells or chlamydospores are formed in compact masses, the shape and consistency varying with different strains. The sclerotia of some strains are usually formed as scattered large irregular oval smooth or woolly masses (specimen plate XXIV. spec. II.) rich in oil globules. In other strains there is a thin flat sclerotial layer spreading over the entire surface of the medium. (Spec. Plate XXIV spec. I.). In still others many small sclerotia of uniform size are formed in an even layer over the substratum (Spec. plate XXV. spec. I.)

In all cases they serve as resting cells or chlamydospores and tide the fungus over unfavorable conditions. Where the cells are compacted into a large mass rich in oils and food material, as in strain B54. Figs. I. plates IV and V, then the vitality is retained for a long period of time.

In one particular strain (3317) which the writer has had under observation, however, the sclerotial cells form not as a compacted solid mass, but as a matted felty growth (Plate X, Fig. 3) of more elongate cells which contain much less oil than the cells of the more common compact sclerotia (compare the two types in Plates IV and V.). In this strain the vitality of these loosely woven sclerotial cells is soon lost.

Figs. 1 and 2 Plate II. shows the characteristic method of germination of the Rhizoctonia chlamydospores. These spores were germinated in a medium of apple broth M191. The germinating cell in all cases was rich in food material, consisting of large oil globules. Very rapid growth takes place and an abundance of food is soon stored in the developing hyphal threads, septa are formed
at varying distances and the hyphae soon take on the characteristic brown color in mass.

In nature sclerotia are commonly formed on the surface of tubers, Figs. 2 and 3, Plate XI, and consequently serve as a means of dissemination of the fungus when diseased tubers are used for seed. On account of their compactness and the inability of formalin to penetrate most bodies, the corrosive sublimate treatment seems to be the only reliable method yet found by which clean seed is assured.

The mycelial strands which serve to further the spread of the fungus over different parts of the plant and through the soil are made up of very coarse dark brown filaments which are capable of enduring conditions, such as, drying and light which would be fatal to ordinary huphal threads. Such mycelial strands are shown in Fig. 1, Plate XI, adhering to the surface of a tuber. Hyphae of a similar character are also commonly found massed in long strands running up and down the stem and forming a dark brown layer around the base of the stem. Such a layer is always found connecting the reproductive layer on the stems above the soil with the vegetative stage on the subterranean part of the plant, probably serving as a carrier of nutrition.
Cultural Characters of the Different Strains of the Fungus.

A cultural study of strains of Rhizoctonia of the potato, obtained from different parts of the United States and Europe, as well as from various points in Oregon, has convinced the writer that there is a wide morphological variation between different strains. Table I. gives the information concerning the source and stage from which various strains have been obtained; also the date of isolation and their accession number.

TABLE I.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>DATE OF ISOLATION</th>
<th>ACCESSION NUMBER</th>
<th>STAGE FROM WHICH ISOLATED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maine.</td>
<td>5/14/14</td>
<td>3333</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ohio.</td>
<td>6/1/14</td>
<td>B 12</td>
<td></td>
<td>sclerotia</td>
</tr>
<tr>
<td>Belgium.</td>
<td>5/14/14</td>
<td>3541</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado.</td>
<td>5/14/14</td>
<td>3517</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York.</td>
<td>5/14/14</td>
<td>NGCT2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin.</td>
<td>5/10/14</td>
<td>#40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon.</td>
<td>10/15/11</td>
<td>B54</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10/25/15</td>
<td>M37</td>
<td></td>
<td>mycelium</td>
</tr>
<tr>
<td></td>
<td>6/18/14</td>
<td>BVD</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/9/15</td>
<td>C37</td>
<td></td>
<td>fruiting layer</td>
</tr>
<tr>
<td></td>
<td>1/9/15</td>
<td>C39</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>11/4/14</td>
<td>C38</td>
<td></td>
<td>sclerotia</td>
</tr>
<tr>
<td></td>
<td>5/25/14</td>
<td>A15</td>
<td></td>
<td>fruiting layer</td>
</tr>
<tr>
<td></td>
<td>7/5/14</td>
<td>R70</td>
<td></td>
<td>sclerotia</td>
</tr>
<tr>
<td></td>
<td>2/19/14</td>
<td>R50</td>
<td></td>
<td>sclerotia</td>
</tr>
<tr>
<td></td>
<td>2/19/14</td>
<td>X5</td>
<td></td>
<td>mycelium</td>
</tr>
<tr>
<td></td>
<td>10/23/13</td>
<td>R2</td>
<td></td>
<td>spore ?</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H1</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H2</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H3</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H4</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H5</td>
<td></td>
<td>spore</td>
</tr>
<tr>
<td></td>
<td>1/5/15</td>
<td>H6</td>
<td></td>
<td>spore</td>
</tr>
</tbody>
</table>

Certain of the different strains have been grown on various media and the following characters noted as the growth developed.
1. General appearance.
2. Rapidity of growth.
3. Texture of mycelium.
5. Size of sclerotia.
7. Coloration of media.
8. Time for appearance of brown color.
10. Sclerotia massed together to small.
11. Sclerotia small scattered.

Soon after growing the various strains on the same culture media, potato dextrose agar, it was quite noticeable that the manner of growth was decidedly different in some strains. It was then that the cultural study was began and the previously mentioned points noted as the growth progressed. The characteristics which certain strains possessed remained constant almost without exception when grown on both potato dextrose and oat agar. After testing each strain on thirty different tubes of potato dextrose agar and ten different tribes of oat agar the following summary of the notes taken at different periods of growth will give the main distinguishing characters for each strain. Figs. 2-3, Plate X.; 1-2 Plate XII and 1-2, Plate XIII will also aid in showing the distinguishing characters and character of growth.

Strain #40

Sclerotia formed over the entire surface. In the first stages, the sclerotia appears as white flaky or flocculant masses. The growth is very similar to that of M 97 except is a little coarser and the sclerotia are larger and do not mass together so much as in M 97. Oil globules seldom formed.
Strain B. V. D.

Oil globules in abundance, sclerotia large, massed. The greater part of the slant is usually covered by a closely adhering sheft of mycelium, free from sclerotia. Sclerotia from very soon after growth commences. Small sclerotia scattered around the outer edge of the media.

Strain B54

Sclerotia form very quick, large and covered by oil droplets similar to B. V. D. in most respects. The large massed sclerotia covered with numerous black, smooth bead like smaller sclerotia resulting from oil droplets.

Strain A15

The only strain showing concentric zonation. This most conspicuous when the sclerotia are forming. Sclerotia large and in concentric rings. Oil globules numerous. Area outside sclerotia covered by a white mycelial growth slight tinged of yellow.

Strain 3317

See fig. 3 plate X also Plate XIII. This strain is remarkable in that no hard compact sclerotia are formed. No oil globules are ever present. The mycelium forms a loose mat like growth over the entire area of the slant. Soon loses its vitality. Very slow in growth.

Strain 3333

Oil droplets formed in limited numbers. growth similar in some respects to B. V. D. and B 54, except the sclerotia are more spreading.
Strain 3344

This strain always forms a dense growth of mycelium at the top of the slant, sclerotic irregular and oil globules usually abundant. Luxuriant coarse mycelium is chief characteristic.

Strain Ngct2

General character of growth is much like #40 but of a finer texture and sclerotia are smaller and form more of an even meted growth over the entire sub-surface.

From the fruiting stages developed from several of these various strains seventy two spore measurements were made. See Table II for details of measurement. A slight variation was noted in the measurement of the spores from different strains, but if a larger number were measured this slight difference would probably be very slight.

The fungus was able to develop on media strongly acid or alkaline. On media which was -5 only a very slight growth took place. Media which was -6 prohibited any growth. The fungus was able to develop on acid media as high as plus 6 but failed to grow on plus 7 or plus 8. The growth on acid media was more luxuriant than on the alkaline media.
<table>
<thead>
<tr>
<th>Strain</th>
<th>No. Spores</th>
<th>Microns Length</th>
<th>Microns Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9.1</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9.1</td>
<td>5.85</td>
<td></td>
</tr>
<tr>
<td>BVD</td>
<td>3</td>
<td>9.1</td>
<td>6.5</td>
</tr>
<tr>
<td>1</td>
<td>10.4</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.4</td>
<td>5.85</td>
<td></td>
</tr>
<tr>
<td>Total Average</td>
<td>19</td>
<td>9.4</td>
<td>6.2</td>
</tr>
<tr>
<td>5</td>
<td>9.1</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.3</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11.7</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>#40</td>
<td>4</td>
<td>10.4</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>9.1</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.4</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13.0</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11.7</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Total Average #40</td>
<td>18</td>
<td>10.1</td>
<td>6.6</td>
</tr>
<tr>
<td>26</td>
<td>9.1</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>B54</td>
<td>2</td>
<td>10.1</td>
<td>7.3</td>
</tr>
<tr>
<td>7</td>
<td>10.4</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Total Average</td>
<td>35</td>
<td>9.7</td>
<td>6.6</td>
</tr>
</tbody>
</table>
RELATION OF THE PARASITE TO THE HOST PLANT.

Infection.

Undoubtedly there are certain periods in the growth of the host plant during which the fungus can most easily gain entrance to the tissues. The period when the greater number of lesions appear seems to be during the first stages of growth of the sprouts, soon after they have started from the seed piece. It is at this time that the lesions seem to spread most rapidly, in severe cases extending the entire length of the stem below the surface of the ground and in many instances completely girdling the sprouts and preventing their further development. Probably the acidity or alkalinity of the soil has something to do with the ease in which the fungus can gain access to the plant. In a personal interview with the writer Dr. H. W. Wollenweber of the U. S. Department of Agriculture stated that in all probability the reaction of the soil had a great deal to do with the extent of lesion injury. He had noted on extremely acid soil, the Elk River Valley near St. Paul, Minnesota, that exceptionally deep lesions were formed on the stems near the surface of the ground. Dr. Wollenweber had also noted this lesion injury to plants on soils showing various degrees of acidity or alkalinity but believed the deeper and consequently more severe canker condition to be limited to soils which were strongly acid. In another instance cited potatoes grown on an strongly acid soil were not subject to the extremely deep cankered condition. Thus in summing up the situation Wollenweber was of the opinion that deep lesions occurred only on strongly acid soils although the more superficial injuries might occur on either an alkaline or acid soil.
Perhaps certain conditions like this in the composition of the soil do greatly influence the nature of the lesions formed, but personal observations of injuries on 20 varieties of potatoes would indicate that the variety attacked influences to a marked extent the nature and depth to which the fungus can penetrate into the tissue. In a test for disease resistance, certain varieties appeared to be able to check the invading fungus after it had once gained entrance, limiting the injury to the superficial parts. In other varieties the injuries were deep and spreading, the plant appearing unable to withstand the attacks. In the cases mentioned the plants were all grown in the same soil under like conditions. Thus it would appear that the soil condition may not be the main factor influencing the severity with which the plant is attacked, but experiments conducted by the writer would indicate that the different varieties have decided influence as to the nature of attacks.

Invasion of tissues.

Soon after invading the plant tissues the affected area becomes brown in color making it easier to distinguish from the white healthy tissue. See plate XX. Sectioning the stems shows clearly the presence of both inter and intra cellular hyphae. The cortical layer is usually most severely attacked, the cells collapsing and in many cases becoming filled with compact brown sclerotia which probably give the characteristic color to the lesions. In case the cankers are deep the cambium layer and fibro vascular bundles are broken down and the pith cells invaded. Sclerotia have been found in the cells of the pith as well as in the cells of the cortex. Figs. II plat VIII of Fig I. Plate X show the character of the sclerotia formation within the cells and the collapsed condition.
of the tissues of the cortex. Figs 1 - 2 Plate IX show the sclerotia
of these cells highly magnified. The material for this study was
collected from inoculated plants in the greenhouse during the month
of December 1915. Short pieces of the stems containing the diseased
areas were cut out and fixed in chrom-acetic solution for four hours,
then washed thoroughly, dehydrated and embedded in paraffin of a melting
point of 55° C. Free hand sections of varying thicknesses were made.
They were then fixed on slides, stained with carbol fuschsin and mounted
in Canada Balsam. This invasion of the tissues of the potato stem
by the Rhizoctonia hyphae causing dark brown sunken areas of various
sizes has both a direct and indirect effect upon the host plant.

Direct Effect on the Host Plant

When the potato plant is attacked by Rhizoctonia while very young,
it is many times injured to such an extent that it is unable to recover.
This condition which is quite common results in poor stands and in
plants of such a weakened character that a poor crop is sure to follow.
In case the plants are attacked later in their development, however,
or are only partially girdled, then a different condition results.
As shown by a microscopic study of the cankered stems, sclerotia are
formed within the different affected tissues, thus probably plugging the
vascular tissues, diverting the food material going from the leaves to
the root system, thus causing an abnormal top development, or stopping
of the upward current by the plugging of the vessels, thus causing
a curling or withering of the leaves a symptom frequently associated
with the disease especially during dry seasons and hot afternoons.
A more extended discussion of this phase of the subject will be contained under the heading, of indirect effect on the host plant.

In cases where the rhizomes are attacked the tuber production is reduced and a stimulation of small tubers is influenced. In many cases the roots and rootlets are so severely injured as to cause a stunted growth of the plant. Small tubers are also many times blighted in much the same way as the stems, the tissue becoming dry and cork like in appearance.

**Indirect Effects on the Host Plant.**

In all cases where Rhizoctonia injury to the subterranean parts of the plant has been severe, certain characteristic developments of the host plant have been associated with such attacks. Probably the most conspicuous development is the formation of numerous small tubers in the axils of the leaves. Another character which is many times noticed especially at harvest time is the formation of numerous small worthless tubers around the base of the stem, although the plant appeared to be healthy and in a most vigorous condition. Unquestionably the above mentioned conditions are secondary effects due to the attacks of Rhizoctonia on the subterranean parts of the plant.

It might not be out of place to briefly review a few of the general morphological and physiological characteristics of the potato plant in order to make clear what takes place in bringing about such a condition. In the first place the tuber represents a much thickened portion of an underground stem called rhizome. It is essential to bear in mind that tubers are never borne on roots. The evidence that such is the case...
is rendered apparent by the following convincing points. First the
tuber bearing structures originate in the axils of leaves and may be
regarded as branches of the stem. Second a rhizome always has
present an apical bud; a root on the other hand has a root cap. Again
rhizomes bear scale leaves at distinct nodes. Roots never bear leaves.
Lastly the internal anatomy of a rhizome is that of a stem.

If a rhizome is allowed to develop normally, that is beneath the
soil in almost total absence of light, the branch or rhizome makes a
comparatively long slender growth without the development of the basal
leaves as is characteristic of stem growth in the absence of light.
Consequently the tuber which eventually forms on the end of the rhizome
if allowed to develop under natural conditions will be borne some
distance from the mother stem. This condition is advantageous in giving
the tubers greater depth and sufficient room for normal development.

If normal conditions prevail the numerous buds which have formed
near the surface of the ground remain inactive since all the food is
readily stored in several large tubers which have formed on the lower
part of the stem. If however a severe attack of Rhizoctonia has occurred
and the various rhizomes have been girdled, as is commonly the case
the manufactured food which normally would be stored in the tubers on
these rhizomes must be deposited in some other part of the plant.
In case the buds near the surface of the ground previously mentioned
have not been destroyed the food is stored here. Soon after
the lower rhizomes have been destroyed these buds begin to enlarge and
form the characteristic little potatoes.
On account of the impetuous vitality of the plant due to its attempt to restore normal activities and perhaps partially due to the loss of many roots and rootlets through the attacks of Rhizoctonia the food which under normal conditions would have been carried away through 3–6 rhizomes is now suddenly forced with equal access into many buds which become tuber like in character but are usually small and clustered close to the stem. In case all of the buds at the base of the stem are also destroyed then the tubers are formed in the buds in the axils of the leaves in any part of the vine. This later condition is the exception but occurs quite frequently where conditions are favorable for the best development of the fungus and in case the variety is especially susceptible to attack, See Fig I Plate XVII.

As stated before this abnormal plant development has repeatedly been observed in association with Rhizoctonia attacks by investigators in different sections of the country. Whether or not the attack of the fungus on the subterranean parts of the plant is the direct stimulant to abnormal development it was thought worth while to carry on some experiment to determine whether or not such a condition could be brought about by artificial methods.

In general two separate experiments were outlined as follows:

Exp. I. The object of this experiment was to produce by artificial means the characteristic "little potato" disease.

In order to make sure that no parasitc organisms entered into the experiment the soil and pots in which the plants were grown were sterilized in the autoclave for four hours at a pressure of ten pounds. The seed used was treated for two hours in mercuric chloride 1-1000.
The plants were grown in a rich leaf mold in six inch pots, kept well watered and in a most thrifty condition. Soon after the young sprouts appeared above the surface of the ground and had attained a height of from four to eight inches, the soil was removed from around the stem and all of the developing rhizomes severed. It was found necessary to repeat this operation several times in some cases because of the development of buds which passed unnoticed in the former operations. In case there were any undeveloped eyes on the old seed piece these were also removed to prevent the storage of the manufactured food in these parts. Soon after the plants had been subjected to this treatment the numerous buds near the surface of the ground which had previously remained inactive began to develop. In some cases this development was confined to a vigorous growth of the buds resulting in a large much branched top, while in other cases the buds took on a tuber-like growth, while in still others there was a combination of these two characteristics. The principle involved however in bringing about this development was undoubtedly as follows: When the subterranean organs for the storage of food in a normal plant are destroyed, and the organs for the assimilation of water and food from the soil are not altered and the manufacture of food is carried on in the same degree then this additional food material is forced into the buds nearest the base of the stem. FigI, Plate XVIII shows a plant which was allowed to develop normally. This particular plant was photographed before the tubers were half mature, but the general characteristic of the plant to store the food in a few large tubers and their development
some distance from the main stem is shown in the photograph. Fig I. Plate XIX will give some idea of the "little potato disease"

Experiment II.

The object of this experiment was to produce by artificial methods the aerial tuber condition such as is commonly found associated with severe attacks of Rhizoctonia. This condition probably results only in cases where all or at least the greater number of rhizomes are severed and where the buds near the surface of the ground are also destroyed or never produced.

The plants for the experiment were handled in general in the same manner as those in Experiment I, but subjected to one additional operation. In this additional operation the buds which developed into small tubers just at the surface of the ground were severed in addition to the rhizomes. Soon after the plants were subjected to this treatment the buds in the axils of the leaves of the lower two thirds of the plant begin to enlarge, those on the lower part of the stem first, and finally developed into the typical aerial tubers. Of the four plants subjected to this treatment all developed aerial tubers, while the four plants left as a check developed normally.

Fig. I of plates XV and XVI shows the tuber formation in the axils of the leaves resulting from this treatment.

The writers experiments prove conclusively that Rhizocloria does produce one or the other or both of these characters when the attack is severe. Fig I Plate XXI shows the condition resulting from inoculation of a plant with Rhizoctonia by placing the sclerotia on the seed piece at the time of planting. In this particular case four of the rhizomes were blighted back soon after tuber development began. The
lesioned areas in the small tubes were darkened and blackened in the infected areas. The tissue was hard and brittle much like the tissue in a lesion on the stems. Isolations from the diseased tissue underneath the surface invariably gave pure cultures of Rhizoctonia. Such an attack of Rhizoctonia as this would probably have resulted in the end in a condition similar to that produced in Exp. I or II by cutting off the rhizomes and developing buds.

Comparative Virulence of Different Strain
of Rhizoctonia.

Table III and IV give the results obtained from the inoculation of tomato seedling by different strains of Rhizoctonia. In this study the plants were grown in conditions as near free from organisms other than Rhizoctonia as possible by a thorough sterilization of the soil and all utensils. The inoculation of the soil and all utensils. The inoculations were made by placing a small amount of sclerotia and mycelium from the various cultures in the vials around the plants. A microscopic examination of several of the diseased plants, showed the presence of an abundance of Rhizoctonia like hyphae running parallel with the stem. Cultures made from the diseased stems always gave pure cultures of Rhizoctonia. Some variation was shown by the different strains in the severity of attack. Strain 3317 was very slow in attacking the seedlings, but this might be expected as this is a slow growing strain on the average agar media.
**TABLE III.**

Experiment to Test the Difference of Degree of Virulence of Different Strains of Rhizoctonia upon Prosperity Tomato Seedlings.

<table>
<thead>
<tr>
<th>Strain</th>
<th>Date of Planting</th>
<th>Date of Checks</th>
<th>Date of Infection</th>
<th>Deaths</th>
<th>Total No. plants</th>
<th>Total No. deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>A15</td>
<td>7/30/14</td>
<td>3</td>
<td>8/5/14</td>
<td>3 1 1 3 1 0 0 1 0 4</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>3317</td>
<td>&quot;</td>
<td>3</td>
<td>&quot;</td>
<td>0 0 0 0 0 0 0 1 0 2</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>3314</td>
<td>&quot;</td>
<td>3</td>
<td>&quot;</td>
<td>0 0 0 3 0 4 1 0 0 14</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>NGCT2</td>
<td>&quot;</td>
<td>4</td>
<td>&quot;</td>
<td>1 0 4 2 6 12 0 2 6 5</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>#40</td>
<td>&quot;</td>
<td>5</td>
<td>&quot;</td>
<td>0 0 0 2 1 8 2 6 1 9</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>B54</td>
<td>&quot;</td>
<td>4</td>
<td>&quot;</td>
<td>4 0 1 0 0 6 2 5 6 4</td>
<td>43</td>
<td>28</td>
</tr>
<tr>
<td>3333</td>
<td>&quot;</td>
<td>6</td>
<td>&quot;</td>
<td>0 0 0 2 0 6 1 14 2 15</td>
<td>48</td>
<td>40</td>
</tr>
<tr>
<td>B12</td>
<td>&quot;</td>
<td>6</td>
<td>&quot;</td>
<td>2 2 0 2 0 7 7 7 6 0</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>EVD</td>
<td>&quot;</td>
<td>6</td>
<td>&quot;</td>
<td>3 3 2 5 2 17 1 4 5 0</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>
### TABLE IV.

Same Tomato Variety

<table>
<thead>
<tr>
<th>Strain</th>
<th>Date of planting 10/1/14</th>
<th>No. checks</th>
<th>Date of infection 10/6/14</th>
<th>Deaths 11/6/14</th>
<th>Total No. plants</th>
<th>Total No. plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>A15</td>
<td>''</td>
<td>''</td>
<td>'92'</td>
<td>92</td>
<td>112</td>
<td>92</td>
</tr>
<tr>
<td>3317</td>
<td>''</td>
<td>''</td>
<td>'77'</td>
<td>77</td>
<td>112</td>
<td>77</td>
</tr>
<tr>
<td>3341</td>
<td>''</td>
<td>''</td>
<td>'90'</td>
<td>90</td>
<td>112</td>
<td>90</td>
</tr>
<tr>
<td>NGCT2</td>
<td>''</td>
<td>''</td>
<td>'92'</td>
<td>92</td>
<td>112</td>
<td>92</td>
</tr>
<tr>
<td>#40</td>
<td>''</td>
<td>''</td>
<td>'93'</td>
<td>93</td>
<td>112</td>
<td>93</td>
</tr>
<tr>
<td>B54</td>
<td>''</td>
<td>''</td>
<td>'92'</td>
<td>92</td>
<td>112</td>
<td>92</td>
</tr>
<tr>
<td>3333</td>
<td>''</td>
<td>''</td>
<td>'93'</td>
<td>93</td>
<td>112</td>
<td>93</td>
</tr>
<tr>
<td>B12</td>
<td>''</td>
<td>''</td>
<td>'96'</td>
<td>96</td>
<td>112</td>
<td>96</td>
</tr>
<tr>
<td>EVD</td>
<td>''</td>
<td>''</td>
<td>'98'</td>
<td>98</td>
<td>112</td>
<td>98</td>
</tr>
<tr>
<td>Check</td>
<td>''</td>
<td>''</td>
<td>''</td>
<td>112</td>
<td></td>
<td>00</td>
</tr>
</tbody>
</table>
Varietal Resistance to Rhizoctonia.

As far as the writer has been able to learn no work has been undertaken to determine whether there is any resistance to the Rhizoctonia disease shown by different varieties of potatoes. In considering the solution of the problem of the control of a soil fungus, such as Rhizoctonia it seems very impracticable to attempt to eradicate a fungus by soil treatment especially where a large area would be involved. If however a variety could be selected or developed that would show marked resistance and still possess the best qualities for domestic use then the problem would be practically solved.

The relationship of the vegetative vigor to disease resistance, the improvement by selection, earliness or lateness of maturity, the cultural methods and the general character of the stem are all points to be considered in a study of disease resistance. Whether or not the different varieties show any natural difference in resistance to Rhizoctonia is a question that would probably involve extensive experimentation and study to gain definite results. Morse in a recent bulletin of Main station makes the statement that Irish cobbler seemed to be more susceptible than Green Mountain as far as he had observed.

The time at the writer's disposal was too limited to permit a thorough working out of the question of resistance, but it was thought that perhaps a clue as to whether variability in resistance existed might be obtained and at least give future workers a starting point.

Two methods have been employed in a limited way hoping that one might correlate with the other.

First, raw sterile plugs were made from different varieties to determine whether or not, any natural resistance was shown in the
physical and chemical make up of the tuber itself and this correlated with the resistance shown by the growing plant. The seed was planted in rich leaf mold to which was added enough sand to make the soil as nearly as possible the ideal soil for the best growth and development of potato plant. At the time of planting each eye on the seed piece was inoculated with strains B54 and M97 to insure like conditions for all varieties at the time of the first growth of the young stems.

The seed pieces were covered over to a depth of three inches.

The following varieties, secured from F. C. Stuart of the U. S. Dept. of Agriculture were used in this experiment. The seed pieces of all of the varieties were in approximately the same stages of development, all buds being in the dormant state.

The following varieties were used in this experiment:

White Ohio  Saxony
Rose #4       Green Mountain
Early Rose    Garnet Chile
Rusty Coat   Early Ohio
Rural N. Y. #2 Early Michigan
Moreton       Irish up to date
Irish Cobbler Pearl
Livingston    Bliss Triumph
Carmen #7     Magnum Bomen
Peerless      
Country Gentlemen
<table>
<thead>
<tr>
<th>Variety</th>
<th>No. Cankered Shoots</th>
<th>No. Healthy Shoots</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Rose</td>
<td>14</td>
<td>6</td>
<td>Most of the cankers were spreading, a few small and localized.</td>
</tr>
<tr>
<td>Green Mountain</td>
<td>17</td>
<td>0</td>
<td>15 of the stems were badly cankered by long spreading lesions. One small tuber was torted and in one case a lateral cankered.</td>
</tr>
<tr>
<td>Rose #4</td>
<td>0</td>
<td>23</td>
<td>All healthy except one stem which had present on one side a long black superficial streak; question as to whether it was caused by Rhizoctonia.</td>
</tr>
<tr>
<td>Saxony</td>
<td>25</td>
<td>0</td>
<td>Every plant severely cankered over almost the entire surface beneath the soil. In the greater number of cases the rhizomes were cut off and one plant was beginning the development of the characteristic rosette appearance.</td>
</tr>
<tr>
<td>Country Gentlemen</td>
<td>10</td>
<td>10</td>
<td>Ten stems healthy. The cankers on the other ten while long and spreading were not deep into the stem as is usually the case.</td>
</tr>
<tr>
<td>Irish up to date</td>
<td>20</td>
<td>0</td>
<td>All badly cankered the entire length of the stem beneath the ground and in most cases completely girdled.</td>
</tr>
<tr>
<td>Irish Cobbler</td>
<td>4</td>
<td>12</td>
<td>The cankers on the four stems were small and localized</td>
</tr>
<tr>
<td>Carman #1</td>
<td>25</td>
<td>0</td>
<td>All badly cankered</td>
</tr>
<tr>
<td>Variety</td>
<td>No. Cankered</td>
<td>No. Healthy</td>
<td>Remarks</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>White Ohio</td>
<td>25</td>
<td>0</td>
<td>All the stems were badly cankered 15 were completely blighted back, the lateral buds having developed, but these were small and stunted</td>
</tr>
<tr>
<td>Rusty Goat</td>
<td>14</td>
<td>6</td>
<td>The stems badly cankered one girdled. One tuber was attacked.</td>
</tr>
<tr>
<td>Early Michigan</td>
<td>7</td>
<td>7</td>
<td>7 cankered serious only 3 cases.</td>
</tr>
<tr>
<td>Magnum</td>
<td>1</td>
<td>9</td>
<td>The one cankered stem was one half girdled.</td>
</tr>
<tr>
<td>Bomum</td>
<td>17</td>
<td>4</td>
<td>17 badly cankered in 12 cases the young developing tubers were rotted and blighted, some of the shoots were completely blighted back. Many rootlets girdled in all plants.</td>
</tr>
<tr>
<td>Peerless</td>
<td>17</td>
<td>4</td>
<td>All cankered in the worst form spreading and deep, covering a great part of the stem. Many were blighted back before reaching the surface of the ground.</td>
</tr>
<tr>
<td>Livingston</td>
<td>30</td>
<td>0</td>
<td>Not a single canker, all thrifty and no attacks noted on any shoot or rhizome.</td>
</tr>
<tr>
<td>Bliss Triumph</td>
<td>0</td>
<td>20</td>
<td>2 shoots were canker free. 15 with small localized cankers. Cankers seemed to be held in check and unable to spread.</td>
</tr>
<tr>
<td>Pearl</td>
<td>15</td>
<td>2</td>
<td>All severely cankered cankers large and deep.</td>
</tr>
<tr>
<td>Rural N. Y.</td>
<td>7</td>
<td>5</td>
<td>All severely cankered cankers large and deep.</td>
</tr>
<tr>
<td>#2</td>
<td>7</td>
<td>5</td>
<td>All severely cankered cankers large and deep.</td>
</tr>
<tr>
<td>Early Ohio</td>
<td>15</td>
<td>0</td>
<td>All seriously cankered cankers large and deep.</td>
</tr>
<tr>
<td>Moreton</td>
<td>23</td>
<td>0</td>
<td>All badly cankered. 18 completely girdled. 7 shoots never reached the surface of the ground see Plate XX Fig. II. Cankers deep and spreading</td>
</tr>
</tbody>
</table>
Definite conclusions cannot be drawn from this limited experiment but such marked results have been obtained that it seems quite probable that there is a great difference in varietal resistance to Rhizoctonia. The plants were grown under as near like conditions as possible and in one case for example where the two varietites, Moreton and Bliss Triumph were grown side by side with the result that one was entirely free from attack and the other, Moreton, being attacked in every case in the worst manner would indicate that a natural resistance exists in some varieties while others are especially susceptible. Another feature worthy of note which was so conspicuous in several cases, was the apparent ability of some varieties to withstand the attack of the fungus after it once gained hold. For instance with the Irish cobbler and Rural New York #2 several of the stems were cankered but in all cases the cankers were very small 1 - 3 m. m. in diameter, while in many of the other varieties the lesions covered over almost the entire stem surface below the surface of the ground. In certain varieties the cankers appeared to be almost entirely superficial while in others the effected areas extended deep into the stem giving it a brittle woody texture, probably due to sclerotial formation in the cells.

With the Peerless variety the small tubers seemed to be subject to the attacks. Fig. III Plate XXI shows the manner in which the developing rhizomes were blackened and attacked. Fig. I Plate XX shows the serious cankered condition of the White Ohio variety. In two cases the first shoots were blighted back entirely and growth was resumed by the laterals. Fig. II Plate XX shows the results of the attack of the fungus on the Moreton variety. In this variety many of the shoots never reached the surface of the ground, the rhizomes and stems, including laterals having been
destroyed in their early stages of growth. On account of slowness of growth of the fungus upon the raw plugs of these various varieties no definite conclusions can be drawn at this time, but from present indications it appears that there will be a correlation between the resistance shown in culture and in nature.

TABLE VIII.

The results of this experiment would indicate the following degrees of resistance and susceptibility of the various varieties:

<table>
<thead>
<tr>
<th>Susceptible</th>
<th>Medium Resistance</th>
<th>Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Mountain</td>
<td>Country Gentleman</td>
<td>Rose #4</td>
</tr>
<tr>
<td>Saxony</td>
<td>Rusty Coat</td>
<td>Irish Cobbler</td>
</tr>
<tr>
<td>Irish up to date</td>
<td>Early michigan</td>
<td>Bliss Triumph</td>
</tr>
<tr>
<td>Carman #1</td>
<td>Magnum Bomum</td>
<td></td>
</tr>
<tr>
<td>White Ohio</td>
<td>Rural N. Y. #2</td>
<td></td>
</tr>
<tr>
<td>Peerless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livingston</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pear</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Ohio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moreton</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table VII.

Varietal resistance as indicated by luxuriance of growth of the fungus on sterile raw potato plugs.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Strain used for Inoculation</th>
<th>Date of Inoculation</th>
<th>No. Plugs</th>
<th>Degree of resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow</td>
<td>B12</td>
<td>9/29/14</td>
<td>5</td>
<td>#</td>
</tr>
<tr>
<td>Money Maker</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotch Rural</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maple Leaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salad</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Six Weeks</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Garnet Chile</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Burbank</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Peer O Day</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Earliest of All</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Lambert</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Burpers Prolific</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Uncle Sam</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Pride of Multnomah</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Early Bower</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Burfres Extra Early</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>German #1</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Early Virginia</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Suttons Reliance</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Sir Walter</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Raleigh</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Gold Coin</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Early Sunrise</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Early Rose</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>King</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Elephant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Victor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Mt. Sp Me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Wonder</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotch Rose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carlos Matchless</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beauty of Four</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaplinger</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 Fold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoroughbred</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evergreen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burbank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SOIL TREATMENT FOR RHIZOCTONIA.

The Table V and VI give the results of an experiment for the control of Rhizoctonia by means of the addition of certain chemicals to the seed bed. In this experiment the plants were set in in twelve inch tile buried in the ground. In this way little of the values of the chemicals were lost by soaking out in the soil and practically all of the soil within the tile was reached by the chemical. The different substances used were diluted in water and applied to the soil three days before the seed was planted. The seed pieces were all inoculated with Rhizoctonia by placing a small bit of sclerotium on the seed at the time of planting. The plants were carefully checked over when mature and all signs of the presence of Rhizoctonia noted. Mercuric Chloride was the only chemical which seemed to have any marked effect upon the development of the fungus. Further tests are necessary for definite conclusions.
**TABLE V.**

Results of soil treatment for the control of Rhizoctonia.

Variety, Early Ohio.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date soil</th>
<th>Date No.</th>
<th>De. Date</th>
<th>Sclerotia &amp; Mycelium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercuric</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chloride</td>
<td>1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>&quot;</td>
<td>1-1000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>&quot;</td>
<td>1-5000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sulphite</td>
<td>1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>&quot;</td>
<td>1-1000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>&quot;</td>
<td>1-5000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphuric</td>
<td>1-250</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>Acid</td>
<td>1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>Lime 100</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>bu per</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime 250</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>bu. Per acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Soluble Sulphur 1-100</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
</tr>
<tr>
<td>&quot;</td>
<td>1-500</td>
<td></td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>Formation</td>
<td>1-250</td>
<td></td>
<td></td>
<td>#</td>
</tr>
</tbody>
</table>
TABLE V (Con't)

<table>
<thead>
<tr>
<th>Min.</th>
<th>Med</th>
<th>Max.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Very little signs of fungus.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Almost entirely free.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Almost free on cankers.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Tubers in good condition, stems cankered in but one case.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Stems covered with mycelium and cankered in several cases. Tuber in good condition</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Stems badly cankered, some girdled. Mycelium spread profusely over stems. Tuber in good shape.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Stems badly cankered, sclerotia numerous in stems. Stems 80% cankered and tubers showing presence of sclerotia in 50% of mycelium quite abundant.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>40% showed sclerotia and 60% of stems were cankered very slightly amount of mycelium present</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Stems badly cankered, mycelium and sclerotia abundant.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Some sclerotia present on tubers 60% of stems cankered.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Sclerotia abundant, cankers on stems in 70% of cases.</td>
</tr>
<tr>
<td>#</td>
<td></td>
<td></td>
<td>Mycelium sclerotia and cankered stems abundant 80%.</td>
</tr>
</tbody>
</table>
**TABLE VI.**

RESULTS OF SOIL TREATMENT FOR THE CONTROL OF RHIZOCTONIA
Rural New York #2 Variety.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date soil Treatment</th>
<th>Date Planting Hills</th>
<th>No.</th>
<th>Date Observe</th>
<th>Presence of Sclerotia</th>
<th>Mycelium on tubers and stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>HgCl₂ 1-500</td>
<td>5/22/14</td>
<td>5/15/14</td>
<td>5</td>
<td>7/28/15</td>
<td></td>
<td>#</td>
</tr>
<tr>
<td>&quot; 1-1000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>&quot; 1-5000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Copper Sulphate</td>
<td>1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>&quot; 1-1000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>&quot; 1-5000</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>H₂SO₄ 1-250</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>&quot; 1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Lime 100 bu per acre</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Lime 250 bu per acre</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Soluble Sulphur</td>
<td>1-100</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>&quot; 1-500</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Formalin 1-250</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>#</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>Medium</td>
<td>Maximum</td>
<td>Remarks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Almost free in all cases.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stems badly cankered.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stems all badly cankered some girdled and dead.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All cankered and sclerotic and mycelium in abundance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sclerotia present upon 40% of tubers 30% stems cankered. Mycelium in abundance on all stems.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40% stems cankered, sclerotia present in 30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50% stems cankered and abundance of sclerotia, tubers ill shaped.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Several stems girdled and mycelium in abundance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>An abundance of sclerotia 60% 40% cankered abundant mycelium.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY.

1. It is becoming more generally known that Rhizoctonia is one of the most serious diseases with which the potato grower has to deal.

2. The disease in nature causes a blighting of the young sprouts, killing of sprouts, the formation of cankers on the stems which many times result in the premature death of the plant. These effects have all been produced by artificial inoculation.

3. The spore producing of Rhizoctonia has commonly been observed during the months of June and July.

4. This stage agrees in every way with the perfect stage as described by Rolfe as *corticium vagum var. solani* (B & C)

Cultures obtained from single spores agree in all respects with the cultures obtained from the vegetative phase of the fungus. The perfect stage has been reproduced in the greenhouse by the inoculation of sterilized plants, with pure cultures of Rhizoctonia.

5. Strain obtained from different isolations show marked morphological variations when grown in culture.

There seemed to be however, only a slight difference in the pathogenicity of the different strains as indicated by the inoculation of various seedlings.

6. The period of most serious infection is undoubtedly from the time the sprout first leaves the seed piece until above the surface of the ground.

7. A microscopic examination of cankered stems would indicate,
that the invading fungus in serious cases may clog the vascular bundles and even penetrate to the vessels.

8. The characteristic "Little Potato Disease" aerial potato formation and rosetted character are secondary effects of the fungus attacks upon the subterranean parts.

9. Both the "Little potato Disease" and aerial tuber formation have been produced in the greenhouse by artificial methods in total absence of the Rhizoctonia fungus.

10. There appears to be a marked degree of resistance shown by certain varieties to the disease. The Bliss Triumph and Rose #4 showing the most marked resistance.

11. Soil treated with mercuric chloride seemed to be quite efficient in prevention the development of the disease but further tests of this method are needed before it can be recommended unreservedly
ADEROLD, R.
Par. 8, No. 19, PP. 620-633, pl. I. Mentions the destruction of white pine trees by attacks of Rhizoctonia strobi.

ATKINSON, G. F.
1892. Some cotton diseases, Alabama Agricultural Experiment Station, Bul. 41: 30-39, fig. 8, 1892.

ATKINSON, G. H.
fig. 55, 1905.

BULLIARD, P.

BERTONI, M. S.
I. No. 4-5, PP. 211-223, figs. 5. Describes at length a Rhiz. sp. he calls subepigea, as destructive to coffee plants.

BUBAK, F.
Centbl., 93, 1903, No. 54, pp. 193. Recommends application of quicklime, good drainage and the rotation of crops as means of control.

BALLS, W. L.

BRIOSI, G.

BARRUS, M. F.
31, No. 803, pp. 796-797. Describes Rhizoctonia sp. as cause of serious cankerimg and rotting of beans.
1082 and 1122. Classifies Rhizoctonia as a less serious disease.

BUTLER, E. J.
50-57. Mentions a species of Rhizoctonia as the cause of a wilt of cotton.


CUNNINGHAM, D. D.
1897. Scientific memoirs. By medical officers of the army of India. On certain diseases of fungal and algal origin affecting economic plants in India. Describes a sclerotial blight affecting potato tubers.

COOKE, M. C.
1904. "Blackleg" of potatoes. (Gard. Chron. 3 ser., 36 (1904), No. 916, p. 28. Author states that what they term blackleg in England is probably the same as what we call Rhizoctonia solani in America.

COOKS, M. T.
1911. The relation of parasitic fungi to the contents of the cells of the host plants. I. The toxicity of tannin. (Del. Sta. Bul. 91, pp. 3-77, pls. 10). Records action of tannin on culture of Rhizoctonia sp.

COLLIGE, W. E.

CLINTON, G. P.

COONS, G. H.

DUMAHÉL, H. L.

DE CANDOLLE, A. P.

DUBY, J. E.
24. DUFOUR, J.  
1895. Nouveau champignon attaquant la pomme de terre.  
(Arch. des sceinc. phys. et nat, de Geneve, 33:94-95(1895).

25. DELACROIX, G.  
Notes Rhizoctonia solani associated with B. solanicola in a tomato disease.

26. DELACROIX, G.  
Renseignments. Agr. pp. 6. The author attributes a disease of asparagus to be due to Rhiz. violaceae.

27. DUGGAR, B. M., and STEWART, F. C.  
1899. Different types of plant diseases due to common Rhizoctonia.  
Bot. Gaz. 27, No. 2, pp. 129. Reports Rhizoctonia attacking carnations and sugar beets, also demonstrated by exp. that Rhiz. caused a damping off of various seedlings.

28. DUGGAR, B. M.  
1899. Three important fungous diseases of the sugar beet.  
New York Cornell, Bull. 163, pp. 337-363, figs. 15. First noticed Rhiz. as cause of root rot of betae in 1898.

29. DUGGAR, B. M., and STEWART, F. C.  
1901. The sterile fungus Rhizoctonia as a cause of plant disease in America.  
N. Y. Cornell Sta., Bull. 186, pp. 51 to 76, fig. 9; gives a list of hosts for the fungus and a discussion of its general morphological features.

30. DUGGAR, B. M.  
1909. A root and stem rot fungus. In Fungous Diseases of Plants pp. 444-462. Fig. 6. Author gives a general discussion of Rhizoctonia.

31. ERIKSSON, J.  
1903. Studies of a root rot of carrots with special reference to its distribution.  
Centbl. Bakt. in Par. 2 Abs., 10(1903) Nos. 22-23, pp. 721-738; 24-25 pp. 766-775, Pl. I, fig. 4. Describes a serious disease of sugar beets due to Rhiz. violaceae.

32. ERIKSSON, J.  
1912. Fungous diseases of beets in Sweden. Meddel. Centralanst. Farkskv. Jourdbkomrddet, 1912, No. 63, pp. 30. Fig. 9; K. Landtbr. Akad. Handl. Och. Tidskr., 51(1912) No. 6, pp. 410-437. Fig. 9. Rhiz. violaceae as cause of rot of sugar beets and author is sure the disease is transmitted through the seed.
33. ERIKSSON, J.
1912. Root felt disease. In Fungous Diseases of Agricultural Plants. pp. 163-167. Fig. 3. A general discussion of Rhizoctonia.

34. ERIKSSON, J.

35. ERIKSSON, J.

36. EDGERTON, C. W.
1913. Diseases of the tomato in Louisiana. Louisiana Sta. Bul. 142, pp. 23. Fig. 3. Rhizoctonia described as cause of damping off of tomato plants.

37. EDISON, H. A.
1913. Damping off and root rot parasites of sugar beets. Abs. in Phytopathology. 3(1913) No. I. pp. 76. Causes seedling trouble, found fungus present on seed.

38. FUCKEL, L.

39. FRANK, A. B.

40. FRANK, A. B. and Sorauer, P.

41. FRANK, A. B.

42. FRANK, A. B. II.

43. FRANK, A. B. III

44. TREEMAN, E. M.
45. FALLADA, O.

46. FALLADA, O.

47. FALLADA, O.

48. GUNTZ, M.
1899. Investigations on Rhizoctonia violaceae. Thuhling's Landw. Ztg., 48 (1899) No. 19, pp. 731-732; abs. in Centbl. Bakt. in Par., 2 Abt. 6(1900), No. 15, pp. 506-507. Potatoes, Jerusalem artichokes, and bush beans were all attacked, when planted in an alfalfa field infested with R. violaceae.

49. GUSSOW, H. T.

50. GUSSOW, H. T.

51. GONDARA, G.

52. GLOYER, W. O.

53. HALHER, E.

54. HALHER, D. E.
55. HARTIG, R.
1888. Untersuch aus d. forstbotan Institute zu Muchen, 1888.

56. HOLBURG, M.

57. HEDGCOCK, G. G.

58. HUME, H. H.
1904. Potato Diseases. Bull. 75. Florida Agr. Exp. Sta. Noted in some cases that from 1/4 to 1/3 of the plants were cut off before reaching the surface of the ground.

59. HEALD, F. D.

60. HEALD, F. D.

61. HEALD, F. D.

62. HARTLEY, C.

63. HARTLEY, C.
1912. The use of fungicides to prevent damping off. Abs. in Phytopathology, 2(1912), No. 2, p. 99. Rhizoctonia sp. causing damping off of coniferous seedlings. Sulphuric acid applied to seed bed gave best results as a preventive.

64. HARTLEY, C.
65. HARTLEY, C.

66. HORNE, W. T. and COOK.
Diseases of tobacco (Estac. Cent. Agron. Cuba, Bull. 1, pp. 17-22. Fig. 4. Mention is made of Rhizoctonia sp. causing a disease of tobacco in seed bed.

67. HALL, J. G.

68. HIBBARD, R. P.
Cotton diseases in Mississippi. Miss. Sta. Bull. 140, pp. 27. Fig. 8. Mentions Rhizoctonia sp. as cause of sore shin. A popular discussion.

69. IVANOFF, K. S.

70. JONES, L. R.

71. JOHNSON, J.

72. KUHN, J.
1858. Krankh. deskulturgenachse.

73. LEVEILLE, J. H.

74. LAMBERT.

75. MARGIN, L.

76. MccALLUM, W. B.
77. MASSE, G.

78. McCREADY, S. B.

79. Mc. ALPINE, D.

80. NEES von Esenbeck, Th. F. L.
1817. System der Pilze Schamme, p. 148, Fig. 135, 1817.

81. ORTON, W. A.

82. PERSOON, C. H.

83. PAMMEL, L. H.

84. PRUNET, A.

85. PRILLIEUX, E.

86. PRILLIEUX, Ed.

87. PEGLION, O.

88. POTEL, H.
89. PRERSON, M. R.

90. P Addock, W.

91. POOL, V. W.

92. RANKIN, W. H.
1909. Black rot of gingseng roots. Spec. crops, n. ser. 8(1909), No. 87, pp. 208-210. Fig. 3. Mention of root rot of gingseng in winter, due to Rhizoctonia sp. Fungus grew equally well on acid and alkalin media.

93. PETHYBRIDGE, G. H.
1910. Potato diseases in Ireland. Dept. Agr. & Tech. Inst. Ireland Jour. 10(1910), No. 2. pp. 241-256, pls. 7; abs., in Farmers' Gaz., 69(1910), No. 7, p. 130, Fig. 2. Mentions black speck scab (corticium vagum solani) and violet root rot (Rhiz. violaceae).

94. PETHYBRIDGE, G. H.

95. RANKIN, W. H.
1910. Root rot of gingseng. Spec. crops, n. ser. 9(1910) No. 94, pp. 349-360, Fig. 1. Rhiz. sp. mentioned as causing a damping off of gingseng seedlings.

96. ROSTRUP, E.

97. ROSTRUP, E.

98. ROSTRUP, E.

99. ROZE, E.
100. ROZE, E.  
1896. Observations on Rhizoctonia of potato. Compt. Revd., 123(1896), No. 23, pp. 1017-1019. Author noted association of Rhizoctonia and Oospora scabies. Rhizoctonia having been noted since 1842, but considered of little importance.

101. ROZE, E.  

102. ROZE, E.  

103. ROLFS, F. M.  

104. ROLFS, F. M.  
1903. A fruiting stage of Rhizoctonia solani, (Science n. ser. 18 (1903), No. 466, p. 729. Author reports perfect stage, but not sure whether a corticium or hypochnus.

105. ROLFS, F. M.  

106. ROLFS, F. M.  

107. SORAUER, P.  
1874. Handbuch der Pflanzenkrankheiten. 2 te Anfl; 2:359: under "Kartoffelgrund."

108. SCHOLZ, E.  

109. STOKLASA, J.  
1898. The root rot of sugar beets. Centbl. Bakt. v. Far. 2, abt., 4 (1898), No. 17-18, pp. 687-694, Fig. 2; abs. in Ztschr. Pflanzenkrank, 9. A microscopic study of tissues of beet seedlings, revealed presence of Rhiz. hyphae.
110. STONE, G. E., and SMITH, R. E.
1900. The rotting of greenhouse lettuce. Mass. Hatch, Bull. 69, pp. 40. pls. 2. Fig. 9 Dgms.

111. STEWART, F. C., and EUSTACE, H. J.

112. STEWART, F. C., FRENCH, G. T., and WILSON, J. K.
1908. Troubles of alfalfa in New York, New York Sta. Bull. 305, pp. 33-416, pls. 12, Fig. I. Mentions Rhizoctonia sp. as causing root rot and damping off of alfalfa.

113. SCHANDER, R.

114. SALMON, E. S.
1908. A disease of sea-kale (gard. chron., 3 ser. 44(1908) No. 1123, pp. 1-3, Fig. 3. Results of seed bed treatments for R. violaceae.

115. STEVENS, F. L. and HALL, J. G.

116. SHEAR, A L.

117. STEVENS, F. L.
1911. Okra wilt (fusariose) Tusarium vasmfectum, and clover rhizoctoniose North Carolina Sta. Rpt. 1911, pp. 70-73. Fig. 4. Numerous reports were received from various parts of the state concerning a root disease of clover, which proved to be a Rhizoctonia species.

118. SHAW, F. J. F.
1912. The morphology and parasitism of Rhizoctonia (Mem. Dept. Agr. India, Bot. Ser., 4(1912), No. 6 pp. 115-153 Fig. 11. Figs. 5). Results of cross inoculation and a general morphological study included.

119. STIFT, A.
120. SHeAR, M. V.
1913. Potato growing in the Saquin and Sacramento Deltas of California. Circ. No. 120. Berkeley, Calif. Estimates loss in delta region due to attacks of Rhizoctonia to be close to 25% of the crop.

121. SElBY, A. D.

122. SElBY, A. D.
1904. Tobacco diseases. Ohio Sta. Bull. 156, pp. 87-107, Pls. 5 Fig. 3. Rhizoctonia reported as cause of call rot of tobacco seedlings.

123. SElBY, A. D.
Soil treatment of tobacco beds. Ohio, Sta. Circ. 59, pp. 3. Fig. 1.

124. SElBY, A. D.
Soil treatment for forcing house. Ohio Sta. Circ. 57, p. 7. Fig. 2.

125. TOUGEROUX de BONDARY.

126. TULASNE, L. R. & C.
1851. Fungi hypogaei. Paris, 1851, p. 188.

127. TAUBENHAUS, J. J.
1913. The diseases of sweet pea. Abs. in Phytopathology, (1913), No. 1, pp. 70. Reports Rhizoctonia attacking sweet peas, under glass out of doors.

128. WARD, H. MARSHALL.

129. WOLLENWEBER, H. W.

130. WOLF, F. A.

131. VAN HOOK, J. M.
Diseases of gingseng. New York Cornell Sta. Bull. 219, pp. 165-166. Fig. 25. Reports a Rhizoctonia sp. causing a damping off of seedlings.
132. UZEL, H.

133. Bailey, F.D.

134. Gussow, H.T.

135. Morse M.J. & Shapovalov, M.

136. Serrine.

137. Drayton, F.L.

139. Stewart, F.C.
EXPLANATION OF PLATES.

Plate I.

Camera lucida drawings, greatly magnified.

Fig. I, II. Of spores of corticium vagum, showing general outline of the spores.

Fig. III. Of basidial cells and spores borne on finger-like sterigma.

Fig. IV. Of mycelium from the corticium layer, showing manner in which the hyphae are interwoven. Also two basidial cells arising from a hyphae, bearing spores, in various stages of development.

Fig. V. Of basidial cells showing connection with parent hyphae.

Fig. VI & VII. Of hyphae of corticium layer.

Plate II.

Fig. I & II. Camera lucida drawing of germinating chlamydospores, showing general method of branching and oil globules.

Plate III.

Fig. I. Camera lucida drawing of vegetative mycelium.

Fig. II. Camera lucida drawing of vegetative mycelium under low and high power.

Plate IV.

Fig. II. Photo-micrograph of a section through the sclerotia, of strain No. B517. Showing the lack of compactness of cells, also absence of short septations as shown in strain No. B54.

Fig. I. Photo-micrograph of a section through the sclerotia, of strain No. B54. Showing compactness of cells, also presence of short
septations in all cells.

Plate V.

Fig. I. Same as Fig. II, Plate IV., but of a much greater magnification.

Fig. II. Same as Fig. I. Plate IV, but of a much greater magnification.

Plate VI.

Fig. I. Photo-micrograph of germinating chlamydospore.

Fig. II. Photo-micrograph of Rhizoctonia hyphal growth over a thin film of potato agar in a petri dish. Showing both the true vegetative hyphae and the first stages in the formation of chlamydospores.

Fig. III. Photograph of cultures of Rhizoctonia showing variations in two different strains grown under like conditions. Constant characters of these two strains.

Plate VII.

Fig. I. Photo-micrograph of culture of Rhizoctonia growing in potato agar. Showing anastomosing of hyphae and general character of growth.

Fig. II. Photograph of potato plugs of different varieties inoculated with Rhizoctonia showing difference in degree of attack.

Fig. III. Cabbage seedlings damped-off by Rhizoctonia, strain C38. The seedlings on the right were not inoculated.

Plate VIII.

Fig. I. Photo-micrograph of chlamydospores. Only those spores rich in food materials, (oil globules show as specks) are capable of germination.
Fig. II. Photo-micrograph of cross section of a potato stem through a lesion, showing sclerotia of Rhizoctonia present in the cells of the cortex.

Plate IX.

Fig. I & II. Micro-photograph of sclerotia in cells of a lesioned stem of potato. Highly magnified.

Plate X.

Fig. I. Micro-photograph of cross section of a potato stem through a lesion, showing sclerotia in the cells and manner in which the cells have collapsed.

Fig. II. Photograph of culture of B54 on potato-dextrose agar, showing difference in manner of sclerotial formation as compared with strain 3317.

Fig. III. Photograph of culture of 3317 grown on potato-dextrose agar.

Plate XI.

Fig. I. Potato tuber covered with Rhizoctonia mycelium and sclerotia.

Fig. II & III. Potato tubers covered with Rhizoctonia sclerotia.

Plate XII.

Fig. I & II. Photograph of cultures of various strains of Rhizoctonia 9 days old grown on potato agar. Showing variations in rapidity of growth and sclerotial formation.

Plate XIII.

Fig. I. Photograph of various strains of Rhizoctonia 8 days old, grown on potato dextrose agar.

Fig. II. Same as Fig. I, but the growth 14 days old. Tubes 2 and 4 are reversed from those in Fig. I.

Plate XIV.
Fig. II & III. Photographs of potato plants, the lower parts of which are covered with the white corticium or fruiting layer of Rhizoctonia. From inoculations in the greenhouse January 10, 1915.

Fig. I. & IV. Photograph of the corticium layer on plants. Collected near Corvallis, June 27, 1914.

Plates XV and XVI.
Photograph of potato plant bearing aerial tubers in axis of leaves. This condition resulting from severing of the rhizomes and the buds near surface of the ground by artificial means.

Plate XVII.
Fig. I. Photograph of potato plant, showing the aerial potato production, resulting from the attack of Rhizoctonia upon the subterranean parts of the plant.

Plate XVIII.
Fig. I. Photograph of normal potato before reaching maturity. Plant showing few but large tubers produced, a luxuriant root system and rhizomes connecting the tubers with the stem.

Plate XIX.
Fig. I. Photograph of potato plant, the rhizomes of which were severed, but the buds near the surface of the ground allowed to develop resulting in the storage of the food in these buds and the production of many small worthless tubers. This condition occurs many times under natural conditions if the rhizomes of a plant are attacked and blighted by Rhizoctonia.

Plate XX.
Fig. I. Photograph of 4 stems of White Ohio variety, showing badly lesioned stems resulting from the inoculation of the seed piece.
at the time of planting.

Plate XXI.

Fig. I. Photograph of the lower portion of a potato plant showing four young blackened tubers, due to attacks of Rhizoctonia. Such a condition generally results in the formation of aerial tubers or many small tubers near the surface of the ground.

Fig. II. Photograph of lower parts of potato stems of Saxony variety badly cankered by attacks of Rhizoctonia. One shoot has been entirely blighted back. From inoculation of seed piece at time of planting.

Fig. III. Photograph of young tubers of Peerless variety attacked by Rhizoctonia, from inoculation of the seed piece at the time of planting.

Plate XXII.

Fig. I. Photograph of lower parts of stem of "Earliest of All" variety, showing black lesion on stem and the stub of the first shoot which was entirely blighted back. Resulting from inoculation of the seed piece at the time of planting.

Fig. II-III-IV. Showing similar conditions to that found in Fig. I, except the plant in Fig. II of the Saxony variety. The variety in III and IV is unknown.

Plate XXIII.

Fig. I. Photograph of raw sterile plugs of Carman No. 1 and Lambert's varieties inoculated with Rhizoctonia. Showing difference in degree of attack of the fungus on the different varieties.

Fig. II. Same as Fig. I. except for different varieties.
Specimen Plate XXIV.
Sclerotia of strains 3317, B54 and M97 grown on potato dextrose agar. The variations in the general make-up of the sclerotia are shown in these specimens.

Specimen Plate XXV.
Sclerotia of strains #40, 3341 and NGCT2 grown on potato dextrose agar. Showing the variations in the general make-up of the sclerotia.

Specimen Plate XXVI.
Sclerotia of strains C38, 3333 and BVD showing the various differences as shown in the other specimen plates.
Specimens in envelopes deteriorated to dust.