FUNGUS DISEASES OF SUGAR BEET.

L. H. PAMMEL.

There is no doubt that intensified culture of the sugar beet has made it much susceptible to the attacks of animal and vegetable parasites. In Europe parasitic diseases of the sugar beet are much more numerous than in this country. Several have long been known to cause serious injury to sugar beet culture.

European growers have long been accustomed to ascribe certain diseased conditions to soil exhaustion. The term "beet sickness" has been given to a large number of poorly defined diseases. Practical growers believe that want of potash or phosphates causes this condition. From the very exhaustive researches of Liebscher and Kuehn it appears that none of the chemical elements have been found wanting, nor has the addition of manure or fertilizers restored the conditions essential for the growth of the sugar beet. It has also been observed that a soil capable of producing a good crop was rendered "beet sick" by the introduction of root parasites. Among the parasites which cause the soil to become "beet sick" certain eel worms (*Heterodera schachtii*) and root-rot fungi should be mentioned. Kuehn has shown that when these enemies are removed from the soil beet culture again is possible. These diseases cause a destruction of the beet itself, but there are other enemies that indirectly lessen the yield, among these Spot Disease of the Beet (*Cercospora beticola*), Beet Rust (*Uromyces betæ*), White Rust of Beets (*Cystopus bltii*) and Downy Mildew of the Beet (*Peronospora schachtii*) are the principal fungi which affect the leaves. Two of these diseases have only been recorded for America: Spot disease and beet rust. To bring together the matter of fungus diseases I give here a short account of the fungus enemies of the sugar beet in America.

Beet Rust.

(*Uromyces betæ*).

This disease is caused by a fungus known as *Uromyces betæ Pers.* and has long been known in Europe where it was described by Persoon. The life history of the fungus was worked out by Kuehn in 1869.[2] In Europe the disease has generally appeared in isolated places and hence has not usually attracted the attention of agriculturists. Sorauer[2] however mentions that for several years previous to 1886 it was quite destructive, while Jubainville[2] and Vesque state that it is on the increase in France.[3] So far it has not been reported in Iowa. The fungus has been reported at different times by several investigators in California.[4] It seems to be the home of this trouble in the United States. Halsted, who found the fungus at Santa Barbara, says, "It was making much trouble for the market gardeners, in some places every leaf of the plant was badly infested and whole rows of beets were dwarfed and discolored by the parasite."

This, like many others, is characterized by having three stages, the æcidio—(cluster-cup) stage, the uredo—(red-rust) stage, the teleuto—(winter) stage. The first or æcidium-stage according to Sorauer occurs on the petioles, leaves and stems of "seed beets." In this stage two kinds of spores are produced, in one kind the spores are contained in flask-shaped receptacles known as the spermogonia. These spores are incapable of germination. The spermogonia appear somewhat earlier than the cluster-cup itself. The cluster-cup when opened contains chains of orange yellow colored spores. The spores are so compact in the cup that they are polygonal in outline. They arise from short threads at the base of the cup and are known as basidia. The æcidio-spores germinate under favorable conditions, the tube entering the leaf of a beet through small rifts known as stomata. In the tissues of the leaf a mycelium is formed which develops in the intercellular

[1]K. Stammer: Lehrbuch der Zuckerfabrikation, Vol. I, p. 176.
[2]Zeitschrift d. landw Centralv. d. Prov. Sachsen 1869, No. 2. Bot. Zeitung 1869, p. 540. Sorauer: Pflanzenkrankheiten, Vol. II, p. 229.
[3]Les Maladies des Plantes Cultivees, p. 171.
[4]Vize: Grevillea, Vol. V, 1876-7, p. 110 Halsted: Bull. Bot. Dept. Ia. Agrl. College, 1888, p 15. Scribner: Dept. of Agr. Report 1887, p. 360. Saccardo: Sylloge Fungorum, Vol. VII, p. 536.

spaces. The thread sends out small lateral outgrowths into the cell known as haustoria which absorb nourishment from it. It requires only a short time until the mycelium collects in certain places beneath the epidermis, from which there arise short upright threads which bear small, one-celled spiny spores, known as uredo-spores. These have small bright spots in the cell-walls which are perforations through which the germ tube passes. This tube enters the leaf through the epidermis. The uredo-spores germinate immediately and spread infection to neighboring plants. Late in the season another kind of spore is found. It is known as the teleuto-spore. They are one-celled, thick walled, smooth and of darker color. They have attached to them a short branch known as the pedicel. These spores occur in sori by themselves on the petiole or in some cases with the uredo-spores. The winter spores do not germinate till the following spring when a tube known as the promycelium comes out of a thin place at the apex of the spore. This tube is branched and bears small lateral bodies known as sporidia. These germinate, and when falling on the proper host i. e., "seed beet" produce the æcidium-stage. Little danger need be expected from this fungus as long as it is restricted in its distribution, though it may become severe enough as Halsted has indicated. Sorauer mentions that in some parts in Germany the leaves are so badly affected that they are worthless for stock. In the matter of checking the disease, stress should be laid on the fact that the æcidium stage only occurs on "seed beets." Affected leaves should be carefully removed and burned.

White Rust of Beets.

(*Cystopus blitii.*)

During the fall of 1890 one of the students of the botanical laboratory, Mr. Zmunt, called my attention to a fungus on sugar beets producing white pustules on both sides of the leaf. Plate IV., Fig. 4. The same fungus was subsequently brought in by another student. Although the fungus has not been common here at Ames I desire to call attention to it since it may prove destructive to this plant as well as the ordinary cultivated beet. The fungus has not so far as I know been re-

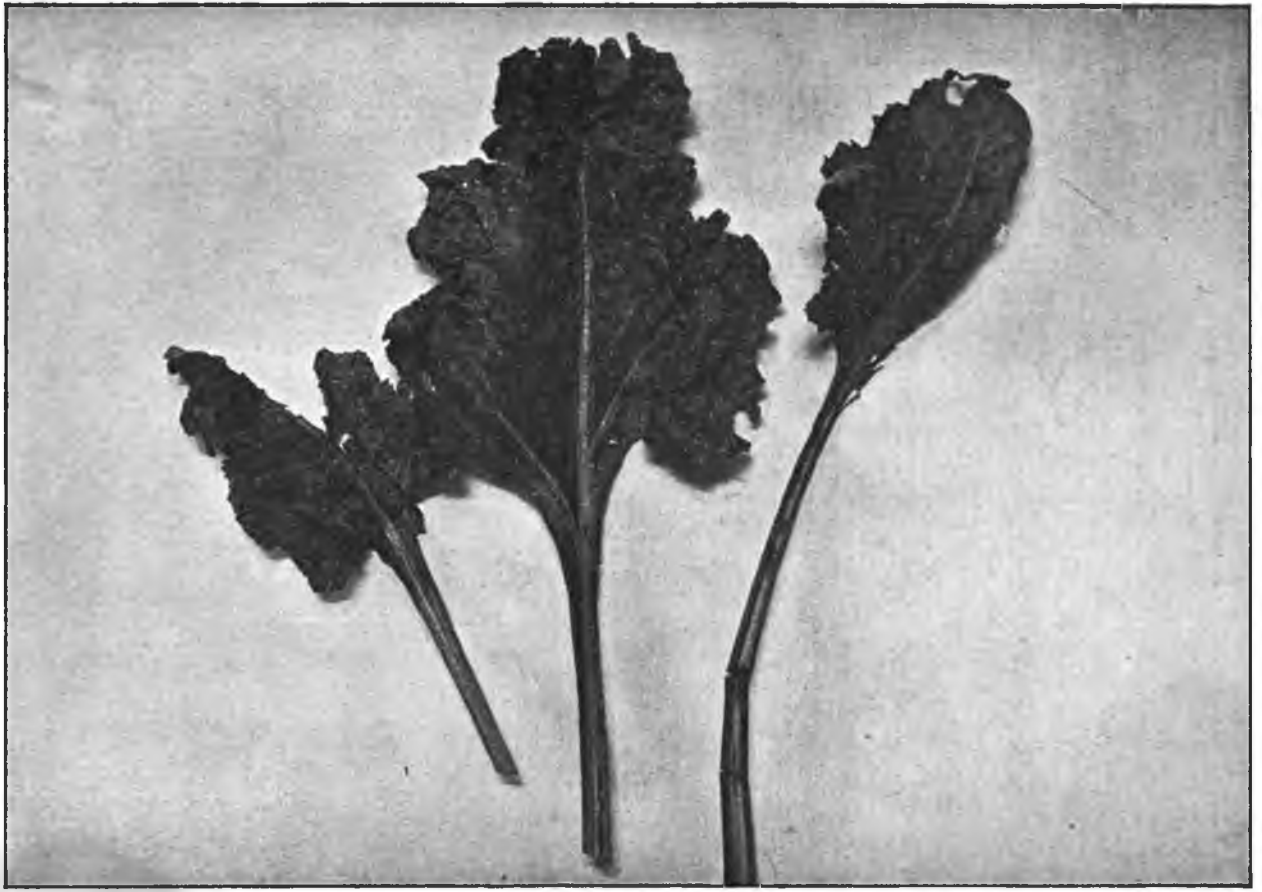


PLATE I.

corded on that host.[5] White rusts are common and more or less destructive fungi on several of our cultivated plants. They are closely related to the potato-rot fungus, (*Phytopthora infestans*), downy mildew of the grape (*Peronospora viticola*) and grass mildew (*Peronospora graminicola*). A species of *Cystopus* is at times destructive to radishes and cabbage and is known as *Cystopus candidus*, another is destructive to sweet potatoes, (*Cystopus Ipomœæ-panduranæ*.) The mycelium of the fungus vegetates in the interior of the leaf occurring in the intercellular spaces. These threads send out small haustoria which take up nourishment from the cells. The fungus threads collect in certain places from which arise erect threads known as conidiophores, Plate VI, Fig. 2c. From the end of this thread, spores Plate VI, Fig. 1 and 2., are cut off, sometimes five or six are found in one chain, the outer being the oldest. The conidiophores and spores are found in large numbers just underneath the epidermis. When sufficient growth has taken place the epidermis or outer layer of cells of the leaf is broken and the white powdery spores are exposed. The outer spore of the series has a thick cell-wall in many cases, and is said not to germinate.[6] Germination of the other spores consists in breaking up of the protoplasm of the spore into eight parts which become zoospores. On escaping from the spore these soon come to rest when a thin cell-wall is formed. It then germinates and enters the stomata. Another kind of spore is formed later in the season known as the oospore. These are the resting or winter spores. I have been unable to find these in the sugar beet leaf, but in a related plant, tumble weed, they are of common occurence. Examination of tumble weed leaf late in the season will show that it contains a large number of minute gray specks. These are only found in the interior of the leaf. In some cases these spores are formed by a process of fertilization, in others they may develop without it.

The sexual method of reproduction is as follows: The mycelium or vegetative part of the fungus enlarges at the

[5]It is not mentioned in Saccardo: Sylloge Fungorum. Farlow and Seymuor: Host Index. Sorauer: Pflanzenkrankheiten Vol. II, p p. 173-76. Frank: Krankheiten der Pflanzen pp. 415-419 and other papers which I have consulted.

[6]DeBary: Comparative Morphology and Biology of Fungi, Mycetozoa and Bacteria, p. 138.

ends of the branches, soon a round cell is cut off, the protoplasm separates into two portions, the outer is used to build up the walls of the spore while the center (oosphere) receives the fertilizing material. The whole is called the oogonium. While the oogonium is forming another branch is sent up from the same thread which produces the oogonium but below it or in some cases, this arises from another branch. This bent or club-shaped body is called the antheridium. It is the male reproductive body. The antheridium enters through the wall of the oogonium and the protoplasm passes into the oosphere. As a result of this fertilization a thick-walled spore is produced, the oospore. The outer part is roughened. Plate VI, Fig. 3.

The oospores lie dormant for sometime. They germinate in the presence of water, the contents of the oospore break up into a number of small bodies which when free are provided with two cilia. These are called zoospores. After a short time a wall is formed about them. The zoospore germinates and enters the leaf through the stomata where an abundant mycelium is developed which in a short time produces the conidia or white rust stage. Although this disease is not so destructive as some of the downy mildews, seldom causing a total destruction of the leaf, except in some cases where the stems or flowers become abnormally enlarged as in the white rust on mustard, radish, (*Cystopus candidus*) it may cause some damage.

Concerning the fungus on beets little can be said. The germination of the conidia has not been observed since the specimines were dry, nor were any of the oospores found; but the fungus in all probability belongs to *Cystopus blitii* which is common on various amaranths (*Amarantus*) and blite (*Blitum*) the latter belonging to the same Family as the beet. At least for the want of better knowledge it can be placed with it.

Spot Disease of Beets.

(*Cerospora beticola.*)

Felix Von Thuemen[7] the well known Austrian mycologist says that without doubt the fungus causing spot disease

[7]Die Bekaempfung der Pilzkrankheiten unserer Culturgewaechse, Vienna, 1886, p. 50.

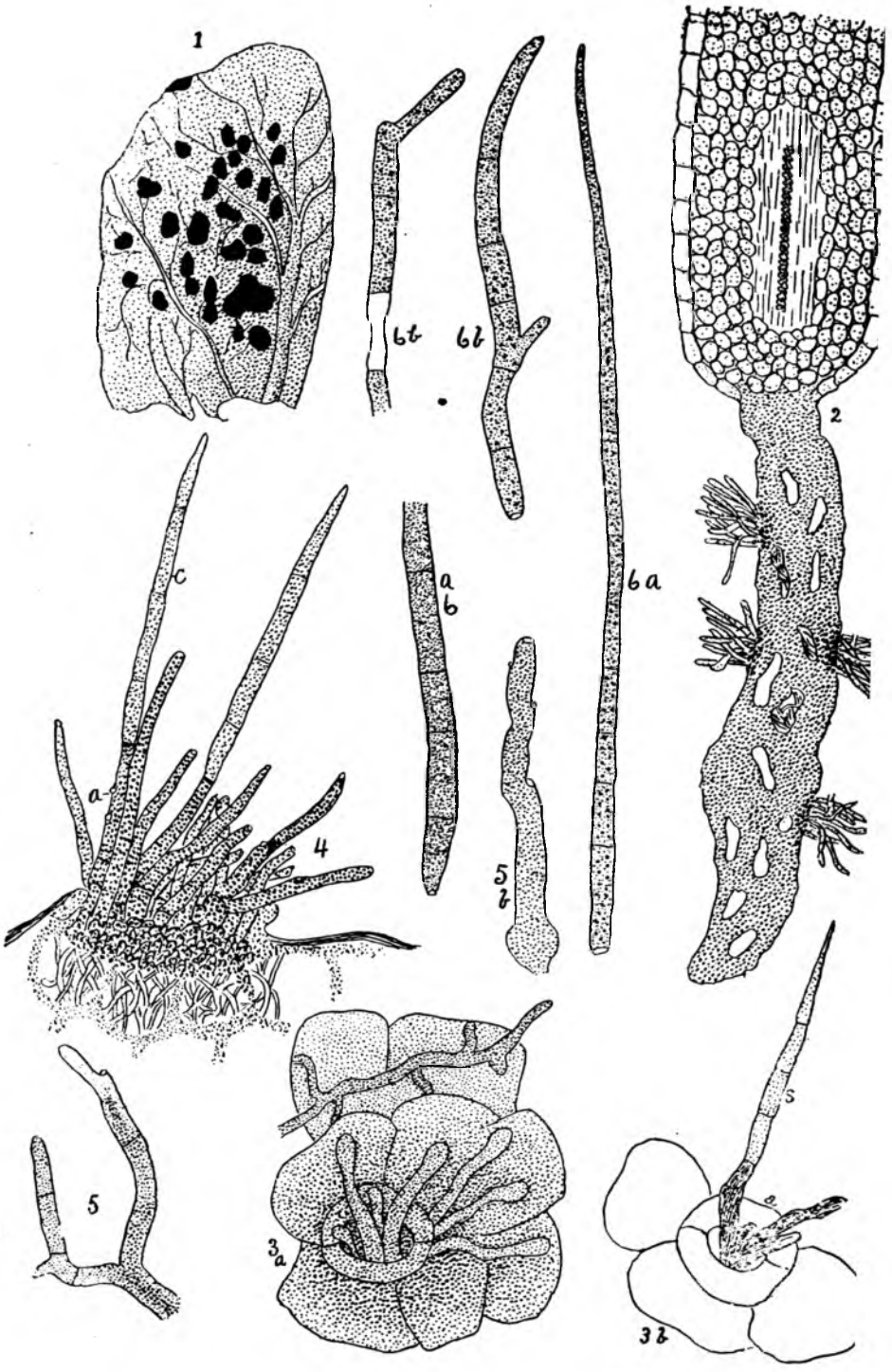
of sugar beets is one of the most injurious of its fungus enemies. Little has been written on this fungus from an economic standpoint. The only account is by Von Thuemen. The fungus is, however, well known in both Europe and America. It having been described by Saccardo[8] in 1873. Other European writers[9] also refer to it, but it is not a disease which has received much attention from agricultural writers. Various American authors[10] have stated that it is troublesome to cultivated beets. It has been sent to me from Wisconsin by Prof. Goff and Michigan by Prof. Beal, in both cases on the sugar beet. Without doubt it occurs wherever the sugar beet is grown.

This disease manifests itself on the leaf by producing round spots, at first not larger than a pin head. Gradually these spots increase in size, becoming round elliptical or irregular in outline (Plate I, plate II, Fig. 1.) Frequently they run together and form one large patch. The spots occur on both upper and lower side of the leaf. There appears to be no difference in regard to the formation of spots on the upper and lower surface of the leaf, occurring as frequent on one side as the other. The spots are of a pale brown color when the leaf is green, but later become darker. The sides of the spot where the spores arise are of a lighter color, the margins being pale brown when the spores are forming. Most of the spots are about one-eighth of an inch in diameter, though some of the larger are nearly one-half inch across. The spots frequently run down the petiole, giving it a black appearance (Plate I). One small leaf, four and one-half by two and one-half inches, had something over one hundred spots of various sizes, and this was a newly affected leaf. In very old specimens the spots are much more numerous. In fact, they were colored black from the effects of the fungus. In badly diseased patches the lower leaves were all black. They were dead or in the process of wilting, while the upper or center leaves were becoming discolored by the fungus.

[8]Fung. Venet. Vol V, p. 189. Fung. Italia, 69. Sylloge Fungorum Vol. IV, p, 456.

[9]Sorauer: Pflanzenkrankeiten, Vol. II, p. 402.
Frank: Kranheiten der Pflanzen, p. 601.

[10]Trelease: Parasitic Fungi, 1884, p. 14. Webber: Catalogue of the Flora of Nebraska. p. 83. Pound: Notes on the Fungi of Economic interest Observed in Lancaster County, Nebraska During the Summer of 1889. Bull. No. 11. Nebraska Agrl. Expt. Station. p. 90. Ellis and Everhart: Enumeration of North American Cercosporeae, Journal of Mycology, Vol. I, p. 20, etc., etc.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The distribution and severity of the disease is somewhat singular. A small number of leaves were found on beets throughout the patch on all of the varieties so far as observations have extended. In certain parts of the field it was much more injurious. Parts of certain rows, especially seed which came from Grand Island, Vilmorin and German Sugar, appeared black in September. Again, this disease appeared in spots of irregular size. The lower parts of the field were affected worse than the higher sandy portions. It certainly appears that adjoining plants may become diseased more readily than distant ones. There is perhaps something in the conditions of the soil or a varietal difference. How is it that the sandier, higher and lighter soils of the field were not affected, while in some low portions it was? Again, in vigorous beets on low ground the disease did little damage. The disease has also slightly affected Red Turnip and Improved Long; also several kinds of Mangold, but not enough to injure the crop seriously. Mr. Pound states that it injures ordinary cultivated beets seriously in Nebraska.

To determine whether the sugar content is influenced in any way by the disease, Prof. Patrick has kindly furnished me the following results of analysis made by him: Sample No. 1—Seven beets, Vilmorin (diseased); mean weight, trimmed, 16 ounces; sucrose, 11.5 per cent. Sample No. 2—Seven beets, Vilmorin (not diseased); mean weight, 15 ounces; sucrose, 11. 7 per cent. The analysis shows very little difference. I think it is safe to say that the amount of sugar in the beet itself is scarcely diminished. The loss comes mainly from a smaller amount of the total product.

Characters of the Fungus.

Examination of one of these spots with a hand lens will show that the tissues of the affected leaf are shrunken, making the border of the spot on the side where the spores of the fungus appear elevated. In the spots small threads that resemble fine hairs can be seen readily. Cross section through a diseased spot shows that the tissues are considerably shrunken. Plate II, Fig. 2; and of brown color. On both sides of the leaf brown threads (conidiophores) pass out usually through the stomata. Frank states that the conidiophores or branches, which bear the spores, always

pass out through the openings of the stomata. This is said not to be the case in (*Fusarium betae Rabh*), a fungus closely related to *Cercospora*. In *Fusarium betae* the threads do not come through the stomata, but along side of it, breaking the epidermis. Von Thuemen states that the conidiophores of *Cercospora* break through the epidermis. Sorauer makes a similar statement. I find, however, that the conidiophores not only pass out through the stomata, but also break the epidermal cells. Plate II, Fig. 3a. The conidiophores seldom occur singly they are clustered or fasicled, usually simple, but in leaves which have been kept moist they are occasionally branched. Fig. 5. They are divided into cells, Fig. 5, and at the upper end are knotty. The conidiophores arise from a mass of short cells of the fungus situated immediately underneath the epidermis. Coming from these short cells and passing into the tissues of the leaf is the mycelium, which at first vegetates between the cells of the leaf in the intercellular spaces. It destroys the cells, causing them to collapse and take on a brown color. The reproductive bodies are borne on the brown threads at certain definite points, Figs. 3 and 4. The irregularities on the branches are due to the spores, which have fallen, leaving a little scar. The spores are long cylindrical bodies which taper towards the extremity. They vary greatly in length; in recently diseased green leaves they are short, but in black and damp leaves they are very long; they are plainly many celled. When leaves are kept in a moist place the spots take on an ash gray color, owing to the immense number of spores which are formed. These are readily seen with a hand lens and look like plant hairs. When placed in a moist chamber the spores germinate, Plate II, Fig. 5b, each cell being capable of producing a germ tube. According to Von Thuemen this enters the beet leaf by way of the stomata. Once in the interior of the leaf a vigorous mycelium is produced, which in a short time gives rise to the brownish several celled, fascicled and occasionally branched hreads (conidiophores), which bear the long needle-shaped many celled nearly colorless spores.

These spores which pass into the soil with decayed leaves, are capable of infecting young beet leaves the following spring. Von Thuemen thinks fungicides are too expensive and do not

prevent the disease sufficiently to pay for the trouble. From what we know of cercospora diseases, this is apparently not true. It is safe to advise the use of both Bordeaux mixture and ammoniacal carbonate of copper to prevent it, although no actual experiments have been made. The advise of Von Thuemen to remove all of the older diseased leaves of beets and destruction by fire is good, but in Iowa where labor is high this will be little resorted to. His own experiments show that in some cases there was a slight increase in the amount of sugar in plants where the diseased leaves were removed. In the treatment of this disease I would also commend the removal of diseased leaves in the autumn and a rotation of crops.

Preliminary Notes on a Root-Rot Disease of Sugar Beets.

It is a well established fact that successful sugar beet culture depends largely on soil and climatic conditions, but all failures cannot be attributed to the absence of these conditions, since certain diseases may cause serious injury and destruction, Whereas the Spot Disease and Rust lessen the yield, the Nematode and Root-Rot Diseases frequently cause a total destruction, they are entirely worthless.

During the early part of August Prof. Curtiss called my attention to the rotting of sugar beets in the ground. It was similar to certain root-rot diseases found on the beet in Europe. It did not appear to be the nematode disease common in Europe, though nematode worms were common in the decaying roots. These, Prof. Osborn informs me, are allied to *Anguilula*. The species apparently only lives on decaying matter.

That there may be no confusion, it may be well to briefly consider a few of the diseases which affect the roots.

The Nematode Disease is one of the principal agents in rendering soil "beet sick" in Europe. It is caused by nematode worms, commonly known as "eel worms" (*Heterodera schachtii*). The worms are found in the small lateral roots forming small white bodies about the size of a pin head.

[11] Die Blattfleckenkrankheit der Zuckerrueben, Cercospora beticola, Sacc. Klosterneuburg, 1882, k. k. Versuchsstation.

These are the encysted females, containing many eggs. In its larval stage the worm lives in the interior of the tissues of the plant, later it moves outward toward the epidermis where copulation occurs. The thread-like worms have a blunt head, in the center of which is the mouth. From the center of the œsophagus a short slender spear is thrown out. This spear is thrust forward, and partially out of the month. It is used to enable the worm to puncture holes in the plant, suck the juice and enter the roots and rootlets. In this way there is a gradual decline in the vigor of the plants, absorption is stopped and assimilation becomes less active, till finally the plant succumbs. So far the nematode disease has not been reported in Iowa, though a related species, *Heterodera radicicola*, has been found common and destructive to many plants in the south. Prof. Atkinson has published several very excellent papers on the subject[12].

THE VIOLET ROOT FUNGUS.—In 1855, Kuehn[13] called attention to a serious root-rot of alfalfa, carrots and mangolds, in which a violet mould closely invested the roots. The disease caused dead patches to form in the field, which are designated "Fehlstellen." The fungus causing the disease is known as *Rhizoctonia medicaginis*. It is the sterile mycelium of the perfect fungus *Leptosphœria circinans*. Mr. Webber[14] has found this fungus on alfalfa in Nebraska. So that it is well enough to call attention to this disease in this connection.

Kuehn[15] has described a second root-rot disease of the beet, *Rhizoctonia betæ*. Our fungus appears to belong to this species. Eidam[16] reports this fungus as very destructive in Germany, where it not only affects large beets, but young seedlings as well. This disease is said to

[12]Atkinson Science Contribution I No. 1 Alabama Agr'l Expt. Station Bull. No. 9, New Series. A New Root-Rot Disease of Cotton, Ala. Agr'l. Expt. Station. Neal Bull. No. 23, Division of Entomology U. S. Dept. of Agr'l.

Eel worm diseases have also been reported by Galloway. American Agriculturalist, 1831, p. ——. Halsted, Annual Report New Jersey Agr'l. Expt. Station, p. 366. Garden and Forest, July 2, 1890.

[13]Die Krankheiten der Kulturgewaechse, ihre Ursachen und ihre Verhuetung Berlin, 1885, p. 24 and 246 Sorauer; Pflanzenkrankheiten, 2nd edition, Vol. II, p. 376 Frank: Krankheiten der Pflanzen, p. 628.

[14]Catalogue of the Flora of Nebraska, p. 76.

[15]Prof. Galloway sends me the following reference: Comes Crittogamia Agraria, p. 340-342.

[16]Untersuchungen zweier Krankheitserscheinungen, die an den Wurzeln der Zuckerrueben in Schlesien seit letzten Sommer ziemlich haufig vorgekommen sind, Jahresb. der schlesischen gesselsch fur Vaterlandische Kultur Bot. Centralb. Vol. XXXV. 1888, p. 393.

PLATE III.

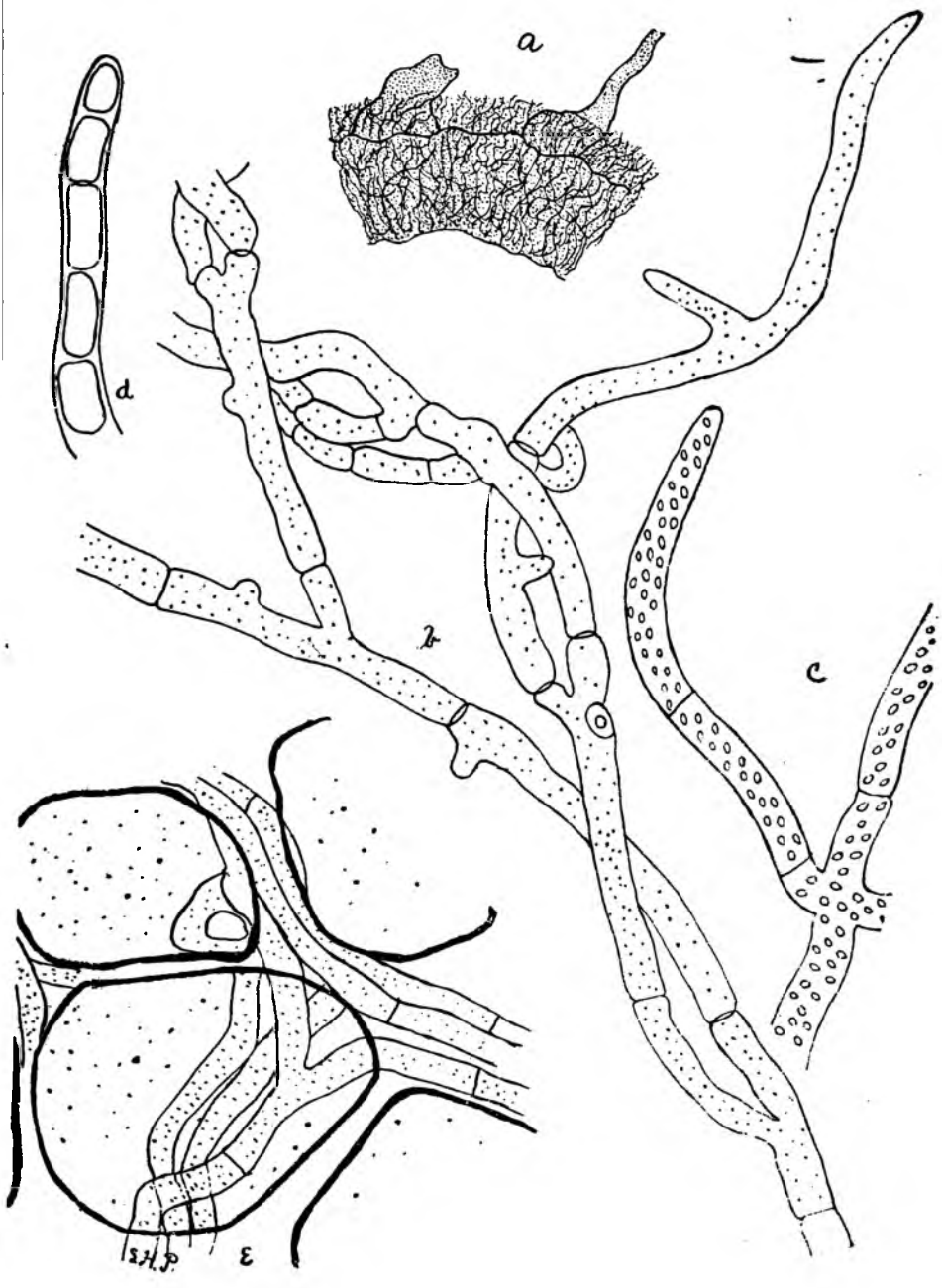


PLATE IV.

produce on the surface of the beet brown spots which speedily enlarge. The diseased tissue is marked by producing a pale brown zone. Eidam observed that the mycelium of the fungus advances in the tissue of the plant, causing a disorganization of the cells of the beets, the fungus apparently throwing off a ferment which prepares the way for the fungus. Sclerotia were also observed.

Prof. Galloway writes me he has referred a disease of sugar beets in Michigan to the same fungus. Prof. Beal has kindly favored me with some diseased beets but these do not show the same characters as the Iowa disease. Our disease manifests itself by a gradual dying of the plant. In plants where the root is not fleshy death is sudden. This is also true of other root-rot diseases, especially root-rot of cotton caused by *Ozonium auricomum*[17] and the violet root fungus (*Rhizoctonia medicaginis*), when it affects alfalfa. The leaves of diseased beets are of pale color and more lax than in adjoining plants. However, these are not always the external manifestations, since diseased beets occur where there are no external symptoms. Like other root-rot diseases it occurs in patches spreading mostly in rows, though in some cases there is a tendency to spread radially. It may affect a single beet in a place, or a dozen or more are diseased. Early in September some of these were completely decayed, the leaves were dead, some beets were less affected, the crown and one side was rotten, with a few, more or less, curled leaves. In some specimens the crown had a large hole, Plate VI, Fg. 6, in others an elongated fissure occurred on the sides, Plate III, upper portion.

The exterior surface of the holes is closely invested with the brown mycelium of the fungus. Plate IV, Fig. *a*. This mycelium extends down the root, slowly advancing till all the smaller roots and rootlets are invaded. The plant then succumbs. It frequently happens that the disease has extended half way down the root, the lower part being perfectly sound. Just how these fissures are formed I have not been able to make out. It may be due to a shrinkage of the

[17] Pammel: Bulletin No. 4, Texas Agr'l. Exp. Station, December, 1888. Bulletin No. 7, Texas Agr'l. Exp. Station, November, 1889.

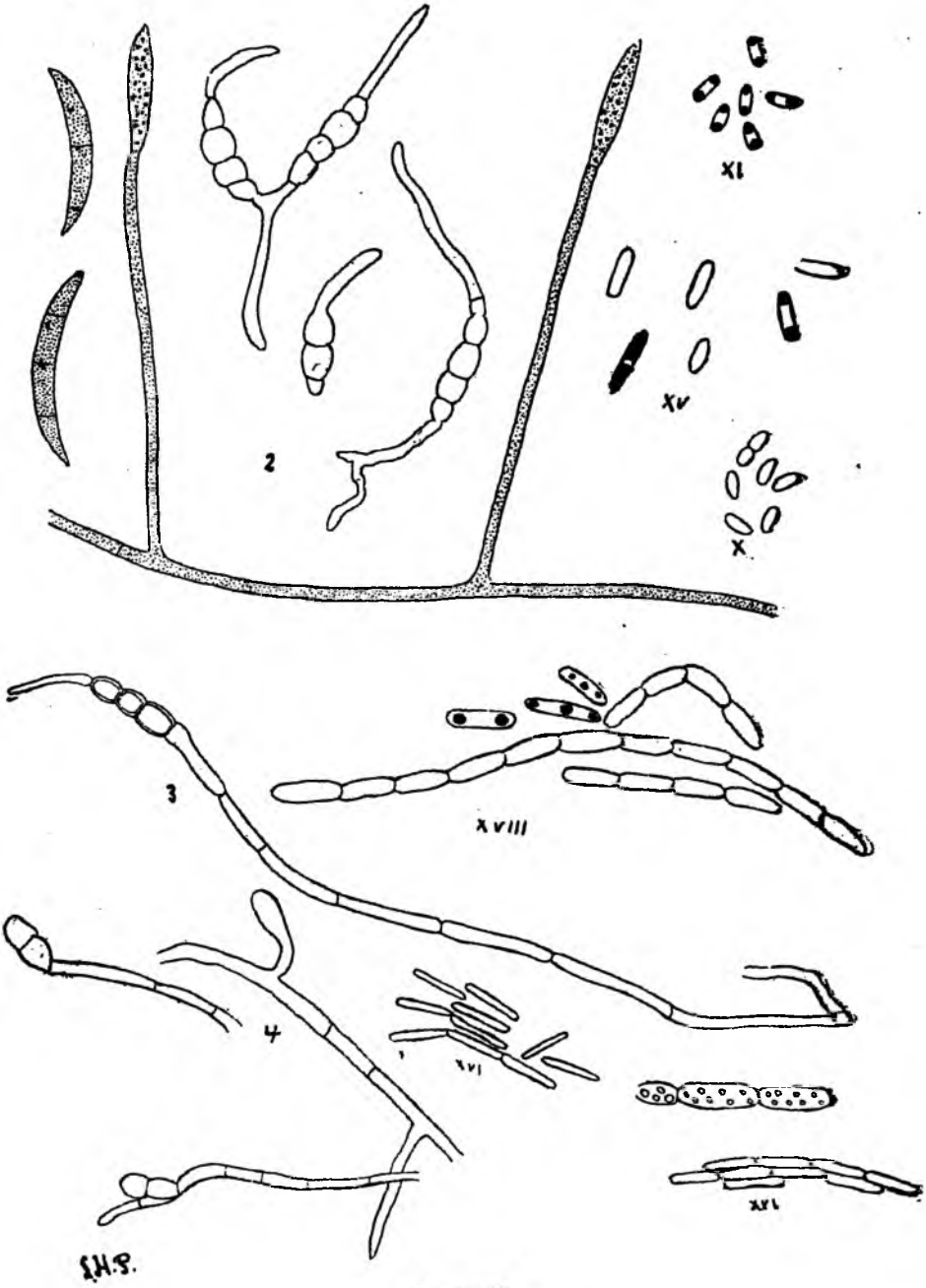


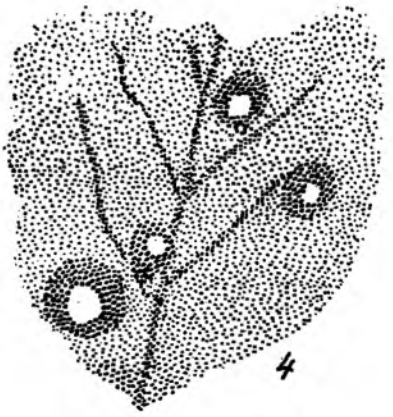
PLATE V.

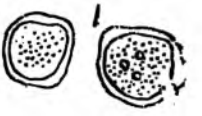
tissues, owing to the attacks of the fungus or a mechanical injury.

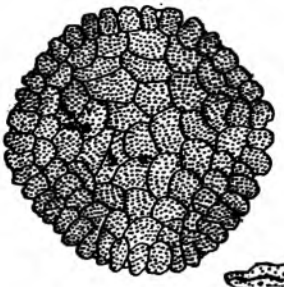
On pulling affected beets up, the diseased part invariably has soil adhering to it, while the undiseased is free. The border line is marked by a brownish color. In very young specimens it is reddish, with the tissues more or less shrunken. A cross section through this part shows that the branched nearly colorless threads ramify between the cells and intercellular spaces. Plate VI. Fig. *e*. Occasionally they penetrate the cell and occur in the cell-cavity. An affected beet placed in a moist chamber is soon covered with a very dense growth of the fungus. Plate VI. Figs. *b*. *c*. and *d*. show threads of the fungus. Every specimen examined contained this fungus, and freqnently many other saprophytic species. Rotting beets give off a very strong odor not unlike that of rotting potatoes.

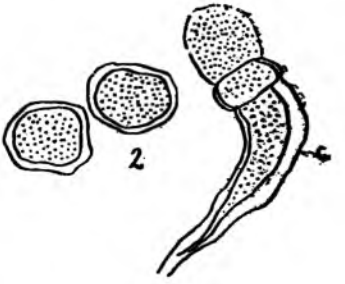
There can be no question that the ultimate rotting is caused by bacteria; several have been isolated. Among them *Bacillus subtilis*, a very common species. A portion of raw beet was taken out inoculated with diseased beet placed in an incubator at 42° C. The following morning it was covered over with the growth of a bacillus. A strong odor of boiled beets was given off, while the beet was black. This bacillus had developed to the exclusion of everything else. A second inoculation was made with a pure culture of the organism, but the results were not very decisive. The raw beet did not take on the sudden blackening, nor was the odor so decided. Some of the other bacteria found are shown on Plate V. Figs. X, XI, XV, XVI, XVIII. Several other saprophytic fungi have been found, among them a species of *Fusarium* forming white patches. This appears to be *Fusarium Betæ*, which has been compared with a *Fusarium* on beet kindly sent me by Mr. Ellis. The *Fusarium* is a secondary growth and is in no way responsible for the disease. Plate V. Figs. 2, 3, and 4. A *Fusarium* unidentified was found a few years ago on decaying beets in cellars. It may be responsible for some of the cellar rot.

Affected beets contained larva of some insects, which was to be expected. Prof. Osborn, who has been looking up the









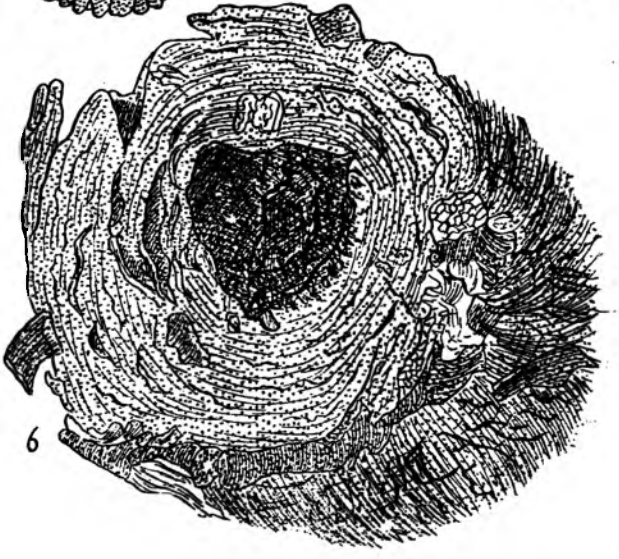


PLATE VI.

matter of insects which affect the beet root, has found several dipterous larvæ, some of them entirely harmless, but one, a speciesof *Anthomyia*, may cause injury to living roots. It is possible that the insects by causing an injury to the roots may give the fungus a chance to enter the tissues. Since little is known of the early history of the fungus, this question cannot be answered. In the majority of cases it appears to start in the crown, working outward and downward. The crown has, of course, the most delicate tissues, and hence would give the fungus an easier chance to work.

It was evident that beets effected by this rot would be worthless for sugar such beets of course would not be used for that purpose. Prof. Patrick was kind enough to make some analyses for me. Several beets showing all stages were selected and compared with healthy beets of the same kind. The seed was obtained from Grand Island. These are his figures. No. 3 diseased, four beets, mean weight 19 oz,, sucrose 5.5. No. 4, not diseased, 7 beets, mean weight 20 oz., sucrose 13.5. Microscopical tests also showed sugar in proximity of rotting tissues.

It is natural to ask can the disease be transmitted? To decide this matter the following experiment was made; one beet was thoroughly washed with a solution of corrosive sublimate and placed on aseptic filter paper. Peices cut out with a sterilized knife then inoculated with portions of the fungus of the beet. The fungus grew, though slowly. It was inoculated again in the crown where it grew more rapidly than on the side.

A second beet was thoroughly washed with well water and inoculated in the crown with the fungus from a diseased beet. The next morning small mycelial tufts appeared. It spread for some distance causing the browning of the tissues. Up to this writing it has not caused the entire decomposition of the beet. It is probable that the soil is much more conducive for this rot than a moist chamber, and there is no doubt that small mites assist in the destruction.

As to treatment, the most suggestive is a proper method of rotation So far as is known the fungus does not occur on any other plant. All decayed beets should be removed from the field and destroyed. It is possible that this fungus may

grow on related plants like goosefoot. If so these should not be tolerated.

Scab of Beets.

Since other beet diseases have been discussed it seems wise to call attention to a disease of sugar beets known as scab. It does not appear to be as common here as it is in North Dakota, judging from the accounts given by Prof. Bolley.[18]. Of the 121 samples from different parts of North Dakota eighteen were found, representing one hundred and eight beets. It has certainly not been common in Iowa for my attention had not been directed to it until I saw an account in bulletin of North Dakota Agriculturai Experiment Station when I made an examination of a large number of beets but failed to find it. I then requested Mr. William Davis to carefully examine the beets of more than fifty bushels as he was putting them into the root cellar. Two scabby beets were found. Prof. Patrick also informs me that he has received a few samples of scabby beets from a very large number sent to him from different parts of the state. Such usually occurred on wet soil and were worthless for sugar. The disease is apparently not common in Iowa. Prof. Bolley's investigations indicate that beet scab is identical with deep scab of potatoes. On this point he says: "There yet remained the fact that the great majority of the sample beets, many of which were known to have been grown upon new land were void of disease, and that in scabby samples the disease was in every case very marked." From answers to fifteen letters of enquiry, "fourteen say potatoes had been a previous crop one was in doubt, but a later communication shows that potatoes were grown within a pace of the beets and both were cultiuated with the same implement." In the case of beet scab found here at Ames it is difficult to say whether it came from the ground which had been in potatoes the previous year, since it was taken from a large pile.

Characters of the Disease.—On the beets examined quite a number of excrescences appear, varying in size from a small pea to three inches across, occurring on the upper as well as the lower part of the beet. Fig. I.

[18]Bulletin No. 4, North Dakota Agrl. Exp. Station, p. 15.

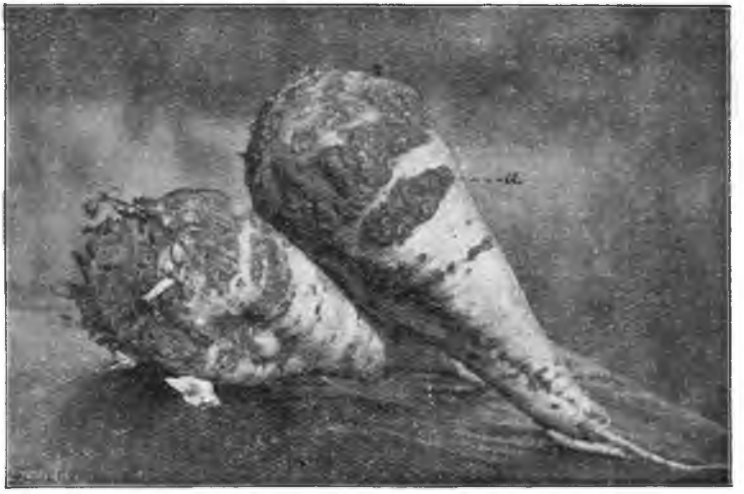


Fig. 1. "Deep Scab" of Potatoes on Beets.—*Bolley.*

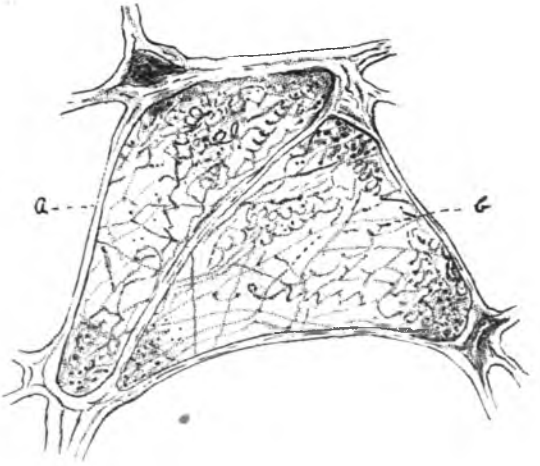


Fig. 2.—Drawing of two distorted cork cells seen in surface section below the ragged surface of a "deep scab," showing the filamentous ramification of the parasite in the cells, and aggregate masses of septated parts of the same in the corners of the cells; *a*, the cell wall; *b*, the parasitic filaments. × about 700.—*Bolley.*

PLATE VII.

A gray mould covered the scabby portions, much more prominent in beets than in potato scab. My experience with the gray mould on potato scab shows that it is very evanescent. It is easily recognized on scabby potatoes either young or old as soon as the potato is dug, but soon disappears. On the sugar beet it does not disappear so readily. The gray mould is still promident after three days in the labratory which is a dry room. It reminds me of a poorly developed white mould of beets (*Fusarium*). A microscopic examination shows that this mould consists of bacteria-like bodies which cohere together "in an amorphous looking mass." The individual bodies consist of branching, rod like or spiral formations. According to the accounts given by Prof. Bolley which appear to be carefully done, the fungus grows readily on nutrient agar and in cultures appears identical with the fungus first isolated from deep scab by Dr. Thaxter[19] in Connecticut. From the very careful work of Dr. Thaxter confirmed by Prof. Bolley, there is no longer any doubt that scab is of parasitic origin and that the minute plant is perhaps closely related to bacteria[20].

Although the facts in regard to beet scab and deep scab of potatoes has not been worked out as fully as desired it will be well to bear in mind that they may be identical, if so beets should never follow potatoes and a reasonable amount of time should elapse before beets are grown on soil where potatoes have been cultivated. Prof. Wilson says a good farmer would not grow two root crops in succession on the same ground.

The author is under obligations to Prof. Bolley for beet scab cuts. Fig. 1, plate II; Fig. *a*, plate IV; Fig. 6, plate VI, were drawn by Mr. Zmunt.

[19]Fourteenth Annual Report Conn. Agrl. Exp. Station 1890, p. 3.

[20]Prof. Bolley read a paper at the American Association for the Advancement of Science 1890. See Proceedings 1890, p. 334 and 335 also Agricultural Science Vol. IV. Nos. 9 and 10, in which surface scab of potato was ascribed to one of the bacteria. His work seems to have been carefully done. Writing Nov. 12 he says: "As to the question whether two distinct diseases exist, I may say that I am even yet much in donbt." (Bulletin No. 4, North Dakota Agl. Exp. Station, p. 30.) It does not necessarily follow that the bacterium isolated by him cannot under certain conditions produce scab. Though no cultures have been made here at Ames I think there can be no question that our disease is identical with that described by Dr. Thaxter.

Summary.

The principal fungus diseases of the sugar beet are Beet Rust, White Rust of Beets, Spot Disease of Beets, Root-rot and Beet Scab. All of these diseases with the exception of rust occur in Iowa. Beet Rust is caused by *Uromyces betæ* and is closely related to bean, oats and other rusts. White Rust of Beets forms white blotches on the leaf, which consist of a large number of small spores. The fungus appears to be *Cystopus blitii*, which occurs on some of the Amaranths. Spot Disease of Beets manifests itself by producing round spots, at first not larger than a pin head, these spots become larger with age and finally cause the leaf to become black in color. The disease is caused by a fungus known as *Cercospera betæ*. The disease can no doubt be checked by Bordeaux mixture or ammoniacal carbonate of copper. Root-Rot is caused by a fungus which appears to be related to *Rhizoctonia betæ*, a fungus discovered some years ago in Germany. It appears to have done some injury to thesugar beet in Europe. The fungus causes a total destruction of beet, it is entirely worthless for sugar. So far the disease has not been reported from other parts of the state, though according to Prof. Galloway it occurs in Michigan. Rotation of crops should be practiced. Two root crops should never follow each other. Beet Scab. This disease has also been found in a few cases. It appears to be identical with deep scab of potatoes. Sugar beets should never follow potatoes. In both diseases (Beet Scab and Root-Rot) care should be used in cultivation. Cultivators and other implements should be kept rigidly clean. Do not pass from a diseased field to one where the disease does not occur. Infectious material is often carried in this way.