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The Late Blight of Barley (Helminthosporium teres Sacc.)

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THE LATE BLIGHT OF BARLEY (HELMINTHOSPORIUM TERES SACC).

BY A. L. BAKKE.

INTRODUCTION.

To the barley grower, no other disease of the barley is probably of such economic importance as the late blight (*Helminthosporium teres*). When active work was begun in the summer of 1909, certain barley plots of the college showed that more than 90 per cent of the plants*, in those plots were infected. The disease presents itself in the form of brownish, orange colored spots, which at first are oval or circular, but later become elongated. As a result of infection, the greater surface of the leaves takes on a yellowish color. In contrast to this effect is the brick red color of the spotted areas. A marked feature, as a result of an examination of a diseased plant, is that a single individual shows all stages of attack. Ordinarily the fungus is noticed in this locality, during the early part of July. Usually at that time, the basal leaves will have become completely dried, while those above will show a progressive decrease to the point where no spots are present. This disease is closely related to the "*Yellow Leaf.*" The last named form is not so destructive for the reason that "Yellow Leaf" singles out individual plants, while the *Late Blight* is broadcast in its attack.

HISTORY.

Helminthosporium teres (Late Blight of Barley) has been known in Europe since 1881. It was found upon withered barley leaves near Padua, Italy, by Bizzazero and was diagnosed, named and described by Saccardo[14] as *H. teres.* In 1889 Briosi and Cavara[2] described this same disease as occurring upon oats. F. Koplin Ravn[12] in 1900 published the results of his extensive investigations in Denmark. Pammel in 1907 and 1908 observed the disease upon barley at Ames, Iowa. In June Pammel, King and Bakke[9], published the results of their observations for the season of 1909**.

DISTRIBUTION.

During the latter part of June, 1909, there was a reappearance of the spot disease of the barley, in the college plots, that had been observed by Pammel in 1907 and 1908. The fungus was observed during the summer of 1909 on barley fields of Minnesota** and Saskatchewan, Canada. Mr. A. G. Johnson of the Purdue Agricultural Experiment Station informed Pammel of the prevalence of a barley disease in the station plots of the South Dakota Agricultural Experiment Station during the season of 1909. He stated that one of the plots was practically destroyed. H. L. Bolley of the North Dakota Agricultural

*Data furnished by Mr. Burnett showed that in many cases 100% were damaged by the fungus. There was also considerable variation with different varieties. The varieties *Oderbrucher*, and *Hulless* were slightly damaged, but the varieties *Primus*, *Hannchen* showed 100% damage. *Hanna* showed 90%; *Manchuria* 5%.

**Bull. Iowa Agr. Exp. Sta. 116.

Experiment Station has found the disease existing in his state. Recently (August 10, 1911) H. T. Gussow of Ottawa, Canada, wrote the following to L. H. Pammel of the Iowa State College Experiment Station:

"This Helminthosporium has been quite serious on our barley plots here this year."

More recently Beckwith[12], in his work on root and culm infections, has shown that Helminthosporium species play an important part in such infections.

CAUSE OF THE DISEASE.

After noticing the physical effect imparted to the barley plants by the disease, the next step was to ascertain the cause. Upon a microscopic examination, conidia or spores of a species of *Helminthosporium* were found in great numbers. In the first publication of this fungus form, the cause was attributed to *Helminthosporium sativum* n. sp.*, but since that time cultural experiments have determined that the disease is due to *Helminthosporium teres* Sacc.[13] The description** given to *H. teres* is as follows:

"Oblong spots on either side of the leaves, becoming dark green; hyphae in clusters, 100u—130u x 12u, cylindrical, acrogenous, erect, rounded on both sides, 100u—115u x 18u: 4-5 divided, not constricted, rather dark green."

This description would hardly be diagnostic for the Iowa species. The characters are as follows[9]: "Spots oblong, irregular, dark greenish, penetrating the entire leaf, hyphae fascicled, 150—180u 60—80u, smoky, reddish brown to dark, somewhat flexed tip, blunt septate, conidia straight or curved, slender, widest at middle, 150—130u=15—20u, pale, greenish gray, 7-14 divided.

A great deal of variation is apparent from the two descriptions. Specimens of the diseased leaves were sent to Saccardo of Italy. He expressed the opinion that the disease was due to *Helminthosporium teres*. Since the time of the last publication, the organism has been grown upon artificial media. Great variations in form and structure are found in all cases. During the summer of 1910, it was the writer's privilege to meet Dr. K, Ravn of Denmark. He had been working upon the *Helminthosporiums* in that country. He further substantiated my opinion that the disease was due to *H. teres* and similar to what had been so prevalent in Denmark during the years 1898 and 1899.

ARTIFICIAL INFECTION.

Even before active experimentation had been commenced, it appeared in all probability that the infection was transmitted through the seed, as was shown by Pammel[10] for *Helminthosporium gramineum* (Yellow Leaf Disease of Barley). Barley grains inoculated with the spores of the fungus were planted in flower pots and covered with bell jars. A short time after the appearance of the first leaves, they became yellow in color, indicating a pathological condition. Microscopic examinations revealed the presence of the mycelium of a *Helminthosporium* species. Spores or conidia were inoculated into the leaves of the corn plant, but in no case was there a resulting infection.

Twenty varieties of barley, furnished by Mr. Burnett, were used in the experiment to ascertain definitely whether the fungus is transmitted by the

*Bull. Iowa Agr. Exp. Sta. 116.

*Bull. Iowa Agr. Exp. Sta. 116: In a recent letter to L. H. Pammel, A. G. Johnson of Madison, Wis., considers *H. sativum* and *H. teres* distinct forms.

**Saccardo, P. A. Sylloge Fungorum.

seed. Twenty-five seeds of each variety were taken, and the spores were placed, by means of a sterile platinum needle in direct contact with the grain. In the second set, twenty-five seeds of each variety were washed with the spores. In each case one row was used as a check. All the seeds were planted in the usual way. The stand from the directly inoculated seeds was very poor. Examination at twenty-four hour intervals indicated that the seedlings lacked vigor. At the end of two weeks' time there were not over seven seedlings to the row. The roots were not in any sense indicative of a healthy state of growth. The conditions above outlined were a contrast to the more vigorous appearances of the check row. The seedlings arising from the seeds that were merely washed with the spores, numbered more than in the first case, but in no case were there more than twenty plants. When these seedlings had attained a height of eight inches some of them began to show yellow demarkations, that were similar to the plants artificially infected and placed under bell jars.

Two rows of oats, with twenty-five seeds to the row were inoculated in the same manner as the first set of barley grains. Two rows were used as check. No effect was observed.

Seeds of *Festuca pratensis* (Fescue Grass) were treated by being washed with the spores. The disease did not show itself with the above named plant as host. This is an interesting fact for the reason that Pammel[9] found spores very similar to those of this species of *Helminthosporium* upon fescue grass in the fall of 1909, near one of the affected barley plots.

These experiments were discontinued after the seedlings had attained a height of ten inches. The results of the above experiments show conclusively that the disease can be transmitted by the seed. Further than this the experiments indicate that this species occurs upon the barley plant alone.

FURTHER OBSERVATIONS.

In the spring of 1910, there was a resumption of experimental work on this fungus at the Gilbert Farm near Elgin, Ill.. Twenty-two varieties taken from the infected plots of the year before, on the college farm, were furnished to me by Mr. Burnett. Frequent observations were made during the growing period, but there was no indication of the disease. On examining the straw later, I was unable to find any spores of *Helminthosporium*. The same thing was true of the plots at Ames, for that year. The reason for this, is the fact that the season of 1910 was unusually dry. Not until the following fall was there any sign of the presence of the *Late Blight*. At that time, through the effect of the fall rains, the disease was abundant upon volunteer plants. The season of 1911 showed very little of this fungus disease as compared to the season of 1909. The abundance and wide spread character of the "Blight" during 1909 shows that a moist humid atmosphere is an important factor in dissemination.

CULTURAL CHARACTERS AND METHODS.

Leaves infected with *H. teres* were placed in sterile petri dishes, where the moisture was excessive, for the purpose of developing a copious supply of spores. Inside of seven days, the conidia had formed to such an extent that a brownish black appearance was imparted to the leaf. In ascertaining the re-

lationship existing between the mycelium and the cells of the host it was found that the mycelium penetrated the epidermis directly and made its way through the intercellular spaces.

As soon as the cause of the disease was determined, efforts were made to obtain a pure culture. Somehow, I was not able to grow the organism upon nutrient agar during the summer of 1909. In the summer of 1910 by the use of .1 of 1 per cent oxalic agar medium, I was able to isolate bacteria, and then by transfers in the ordinary way, pure cultures have been easily made. After having once succeeded in obtaining a pure culture, the organism was transferred at different times to nutrient agar, and upon this medium growth was more abundant and its action quicker than when grown upon the acid medium. In all cases a black pigment is imparted to the medium. Better success, as far as pure cultures, was obtained in inoculating tubes, in which leaves of barley were placed with the addition of about 5 cm. of water. The organism upon this leaf medium grows very rapidly.

MYCELIUM AND CONIDIA.

In noting the growth of *Helminthosporium teres*, it is convenient to begin with the conidia. The germ tubes first come from the basal and apical cells; later other germ tubes may arise from the remaining cells under favorable conditions. As many as three have been observed at one time growing upon nutrient agar. Noack[7] has figured conidia with four germ tubes appearing at the same time for *H. graminium* (Yellow Leaf Disease). In most cases, however, only two germ tubes will be noticed, one from the apical cell and one from the basal cell.

In a favorable medium, like sterile barley straw, under moist conditions, the mycelium develops copiously. The early mycelial threads are septate, branched and fascicled. In older threads, the cells are constricted somewhat in the center. In ten days after the sterilized straw is inoculated, the mycelium is distributed over the entire surface. After this period, the white character is lost and instead, a dark color is imparted. This is due to the large number of conidia present.

The conidia arise from the tips of the conidiophores, and are so loosely attached that a gentle breeze or a small drop of water coming in contact with them will cause a separation. New conidia will then be formed. This accounts for the difficulty of observing the conidia attached.

In giving the characters of the spores, the description indicated considerable variation with reference to color. It has been found that the age of the conidia is a factor that determines this point. The younger conidia will be of a decided greenish tinge, and vary from a light to a dark color, while the older ones are much darker, olive colored, or a gray black. But cultures grown under like conditions are found to be the same.

SCLEROTIA.

After the culture tubes containing the conidia or spores of *H. teres* have undergone dessication for a time, there is a clumping together of the mycelial threads. On examining these clumps, the sclerotia appear as black masses that do not conform to any particular shape. These sclerotia vary in size from 250u-600u in length and 150u-350u in width. Sclerotia develop readily

upon sterile straw as well as upon nutrient agar. That *Helminthosporium* species produce sclerotia was first noted by Hecke[4] in the case of *H. graminium*. Ravn[12] has observed the same thing with reference to *H. teres*. Noack[7] has further proved that sclerotia are a factor in the life history of *H. gramineum*, while Diedicke[3] has proven the same thing true for *Helminthosporium* species occurring upon *Bromus asper* Mur. and *Agropyron repens* (L) Beau.

PYCNIDIA.

The next type of spores, the *pycnidiospores*, are present in the pycnidia. They occur upon sterile straw cultures that have undergone an extended period of dessication. After a month's interval under the above perscribed conditions, grayish white masses appear which after a time form a dark interior. These bodies or pycnidia are on the average 300-375u wide and 450-600u long. Culture tubes of nutrient agar containing sclerotia and conidia, have not in a single instance developed pycnidia. The pycnidiospores are exceedingly small being ordinarily 1-1.5u wide and from 2-4u in length. The walls are thin and the unicellular forms are held together by a sort of a slimy mass. Ravn germinated these spores upon beer wort but compared to the conidia they are slow to germinate. After an interval of five days they began to swell and later developed hyphae. He adds that it took fourteen days for a pycnidiospore to develop sufficient mycelium to be observed by the naked eye.

PERITHECIA WITH ASCI.

In all probability, *H. teres* has a perithecial form. It also appears as if this form should make its appearance upon sterile straw. Ravn in his publication of 1900 believed that the sclerotia were unripe perithecia. Diedicke from his work upon *Bromus asper* Mur. and *Agropyron repens* (L) Beau, came to the conclusion that *Helminthosporium* species are a part of the life history of a *Pleospora species*. Fritz Noack[7] has proven that *H. gramineum* has the perfect form *Pleospora trichostoma* Wint. Noack found the sclerotia occurring upon barley leaves in the field. These, later developed perithecia in their interior. This further substantiates Ravn's statement, previously made in this paper. In many cases two perithecia would be formed. By subjecting the perithecia to a temperature of —10 Degrees C. for a month, Noack succeeded in germinating the ascospores immediately, Johnson[6] has called attention to the fact that the ascogenous stage of *H. gramineum* occurred in Ireland in 1907. Noack's work would, therefore, indicate that *H. teres* has a perfect stage similar to the one reported for *H. gramineum*.

GROWTH AND TEMPERATURE RELATIONS.

The conidia germinate quickly when placed in distilled water. Ravn caused increased germination by adding a small amount of beer wort. When conidia are transferred to any ordinary media, conidiophores and conidia develop very readily.

On examining cultures that have dried out considerably, it was found that the structure of the conidia had changed; there appeared to be a shrinking or departure of the respective divisions of the conidium from the outside wall. In some cases there was a wavy undulating surface imparted, while at other times the outline was uniform. This same apparent shrinkage was noticed when spores were mounted in glycerine. From all appearances no detrimental

effect is imparted to the vitality of the spore, for transfers made from such a culture showed as much growth in a given time as a transfer made from a culture that does not possess this character.

The growth and development of the conidia under different degrees of temperature is a point of considerable interest. Cultures kept in the ice box, where the temperature was on the average 5 degrees C., showed considerable growth at the end of a period of seven days. Cultures at room temperature showed good growth at the end of 72 hours. The optimum temperature for growth took place between 23-25 degrees C. At this temperature enough conidia had developed at the end of 24 hours to impart to the medium the dark pigment, characteristic of all cultures of *Helminthosporium*. The same general conditions with reference to temperature apply to sterile leaf cultures.

The amount of moisture plays an important part in the development of the conidia. Where sterile leaves were used as a medium without the addition of water at optimum temperature conditions growth could not be induced. In the tubes where about 5 cc. of water had been added, the growth was luxuriant. This point further emphasizes the fact that the amount of moisture plays an important role, not only in cultural work but in the field as well.

INFECTION.

The carrying over the fungus from one year to another is an important matter from a practical point of view. In this respect the conidia are the important factors. The infection from the conidia may be placed under two heads: (1) the primary conidia; (2) the secondary conidia. The primary conidia are responsible for a direct infection of the seed, and the transmission to the first leaves. The secondary conidia are derived from the primary spores and serve to spread the disease to unaffected parts. These conidia developing in turn may, under favorable climatic conditions, destroy the entire field.

The work of H. L. Bolley[1] in regard to the soil as an agent in carrying certain cereal diseases is important. The "worn out" soils so commonly described as due to a lack of chemical constituents, are due to the presence of such fungi as *Helminthosporium* species.

Although the complete life history of *H. teres* is essential in placing the fungus in its right place as far as classification, yet all forms are not essential for the propagation of the disease in nature. The possible methods of infection may be summed up as follows: (1) by mycelium located in the glumes; (2) by conidia that are upon the seed or in the soil; (3) by sclerotia that are in the soil or upon dead leaves or straw; (4) by pycnidiospores that may form upon the straw, of barley grown the previous season; (5) by means of ascospores.

REMEDIES.

a. Resistant Varieties.

Whether or not certain varieties are more resistant to this particular fungus, is a subject that will need further investigation. From a general study of the college barley plots in the summer of 1909, the variety known as *Chevalier* was particularly susceptible, while *Oderbrucher* was practically exempt. It also appeared as if the early varieties were not attacked to the extent that the later

varieties were. Ravn came to the conclusion that as a general thing, the two rowed barley was more resistant than the six rowed barley. But in a season, when the disease is wide spread and deep seated, and where there is an indication of a repetition the following season, other remedies must be sought.

b. Treatment of the Seed.

It has been noted that the seed is a source of infection. Is there then a remedy to prevent the spread and propagation of the disease from the mycelium and conidia in the seed? For the most part this question can be answered in the affirmative. Rayn has found that Jensen's hot water treatment is effective in dealing with both *H. teres* and *H. gramineum.* This consists in placing the seed in cold water, which is gradually heated to a temperature between 52-53 degrees C., and allowing the seed to remain for five minutes. The seed is then cooled by being placed in cold water and later dried. A short time afterwards the seed can be sown. In addition Ravn has modified the above process slightly, and this gives better results. The plan consists in placing the seed in glass receptacles and in pouring over the grain sufficient water to cover. The grain is allowed to soak for a period of four hours at a temperature from 10-15 degrees C. The water is then poured off, and the receptacles covered with glass plates, until the next day. At that time the seed is transferred to bags and immersed in water. The water is heated to a temperature between 52-53 degrees C., and allowed to remain for five minutes. Afterwards the seed may be sown. Where this latter treatment showed no infection, the former gave 2.3 per cent while the untreated 12.9 per cent. Hollrung[9] suggests that the seed be treated about a month or a month and a half before being sown. This point does not possess particular significance, as fresh infection may result especially when grain is placed in old bins. Professor Potter[11] in his paper on the "Deaf Ear of Barley" has called attention to the experiments that were performed at Cambridge University. Where a 10 per cent solution of copper sulphate was used all traces of a production of diseased plants were lost sight of. But copper sulphate has its disadvantages in the fact that it injures the seed. In 1907 formalin was tried out. The first solution applied consisted of one part formaldehyde to 240 of water; while a second solution consisting of one part formaldehyde to 160 parts of water was also used. Seeds treated by the first solution showed 2.5 per cent sick plants, while in the latter .9 per cent. The crop harvested by the second method showed a better yield as well as better filled seeds. Kuhn's* treatment where seeds are placed for 14 hours in a ½ per cent solution of copper sulphate, and later soaked in milk of lime, as well as the potassium sulphide (½ per cent solution in water) method of Kellerman and Swingle** were both used by Ravn and Potter with good results.

In taking these different seed treating remedies into consideration the formalin method with a strength 1 to 160-200, will be the most effective. Professor Potter says with reference to *H. gramineum*: "It would appear therefore that the best remedy is to be found in 'pickling' of the grains by means of which the fungus is destroyed, while the power of germination remains unimpaired."

*Report Kansas Agr. Exp. Sta. 1889.
**Report Kansas Agr. Exp. Sta. 1890.

c. Time of Sowing.

The time of sowing is another factor that enters in. From the cultural experiments that have been outlined, it is apparent that the temperature has considerable influence. From this fact it is at once evident that barley placed in the soil at a time when the temperature is 15 degrees C., will not offer the conditions when it is 24 degrees C. It is therefore advisable to get the seed into the ground when the temperature is sufficient for complete germination of the seed, and where the growth of the fungus is held in check.

d. Volunteer Growth.

The remaining stubble and the volunteer growth play a part in the transmission of the disease from one season to another. These young plants continue to propagate the conidia, while the straw harbors the pycnidia and sclerotia. Where a field has been in bad shape it is advisable to burn over the stubble before plowing.

e. Soil Sanitation.

The question of soil sanitation is one that has an important bearing on the transmission of the spores of *Helminthosporium species.* Serious damage can be imparted to our cereal crops when the soil in which these crops are grown is filled with spores of various parasitic fungi. As a result the tender seedlings must undergo a struggle for existence that is possibly not equaled at any later period. In Germany, this fact was long ago established for certain crops like the sugar beet and clover. It was shown that these crops were not remunerative because the soil was inoculated with numberless parasites like *Rhizoctonia.* Pammel found the same thing to be true in the case of the root rot of the cotton (*Ozonium auricomum=O. omnivorum**).

Professor Bolley of North Dakota has recently brought this matter of sanitation to the attention of agriculturists. In his work on flax raising, he found that the farmers of that state were putting flax growing aside for the reason that it was not profitable. These "flax sick" soils were found to possess all the chemical constituents and compounds that go to make up good soil. In an address before the Fifth International Dry Farming Congress at Spokane, Bolley adds: "But I may state that the three most destructive parasites taken in their order are one or more species of *Helminthosporium*, one or more species of *Fusarium*, the type of fungus which produces the wheat scab and flax wilt, and one or more species of *Colletotrichum.* These are universal and effective on roots and leaves, stems and seeds, and various species of *Macrosporium* and *Alternaria* are great blighters of seed and destructive both on straw and on grain especially at germination time. If you declare for careful seed selection in all cases, careful seed disinfection at all times, the formation of a well aerated but compacted seed bed, and for an extensive rotation of crops of as wide spread a character as possible, you of the new dry land region of the West, have the greatest possible opportunity to prove to the world that it is not necessary to lose a crop of such importance as linseed from among your rotations nor is it necessary that your wheat fields yields should fall from the now promising ones of thirty to sixty bushels to the general average of twelve to fifteen."

*Bull. Ia. Agr. Exp. Sta. 15:242-251. 1891.
Bull. Texas Agr. Exp. Sta. 4:1-18. 1889.

FUTURE INVESTIGATIONS.

It was my purpose when I first commenced a study of this disease in 1909 to be able to obtain the complete life history, before publishing any account. But as the disease is of comparative recent origin in the United States and Canada, and as the disease in the places reported is more destructive than has been recorded for either Germany or Denmark, it was thought best to give forth the results of my observations and investigations to serve the purpose, possibly, of assisting in keeping this disease, and similar allied ones, in check.

CONCLUSIONS AND SUMMARY.

1. *Helminthosporium teres* Sacc., known in Europe since 1881, was first discovered in the United States in 1907 at Ames, Iowa, but was not destructive enough to cause appreciable loss until the season of 1909.

2. *Helminthosporium teres* Sacc., occurs upon the barley alone and cannot grow on any other host.

3. *Helminthosporium teres* Sacc., causes greatest destruction through the formation of its conidia. Further than this, pycnidiospores and sclerotia have been developed culturally. In all probability perithecia, with asci and ascospores develop from the sclerotia.

4. Inoculation experiments verify the fact that the disease is largely transmitted by the seed.

5. Temperature and moisture play an important part in the development of the disease. Seed should be sown when the temperature is sufficient for entire germination but low enough to retard the growth of the fungus.

6. Disease can be best checked by treating seed with formaldehyde. Soil sanitation methods are important factors in following out remedical measures.

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DESCRIPTION OF PLATES.

PLATE 1.

1, 2, 3, 6.—Conidia.

5, 7, 8.—Conidia attached to conidiophores.

(Drawings have been recopied by Charlotte M. King.)

PLATE 2.

1, 2, 3, 4, 5, 6.—Conidia germinating.

7.—Portion of mycelium.

8.—Portion of leaf affected by *H. teres*.

PLATE 3.

1.—Sclerotium.

2.—Pycnidium.

3.—Pycnidiospores.

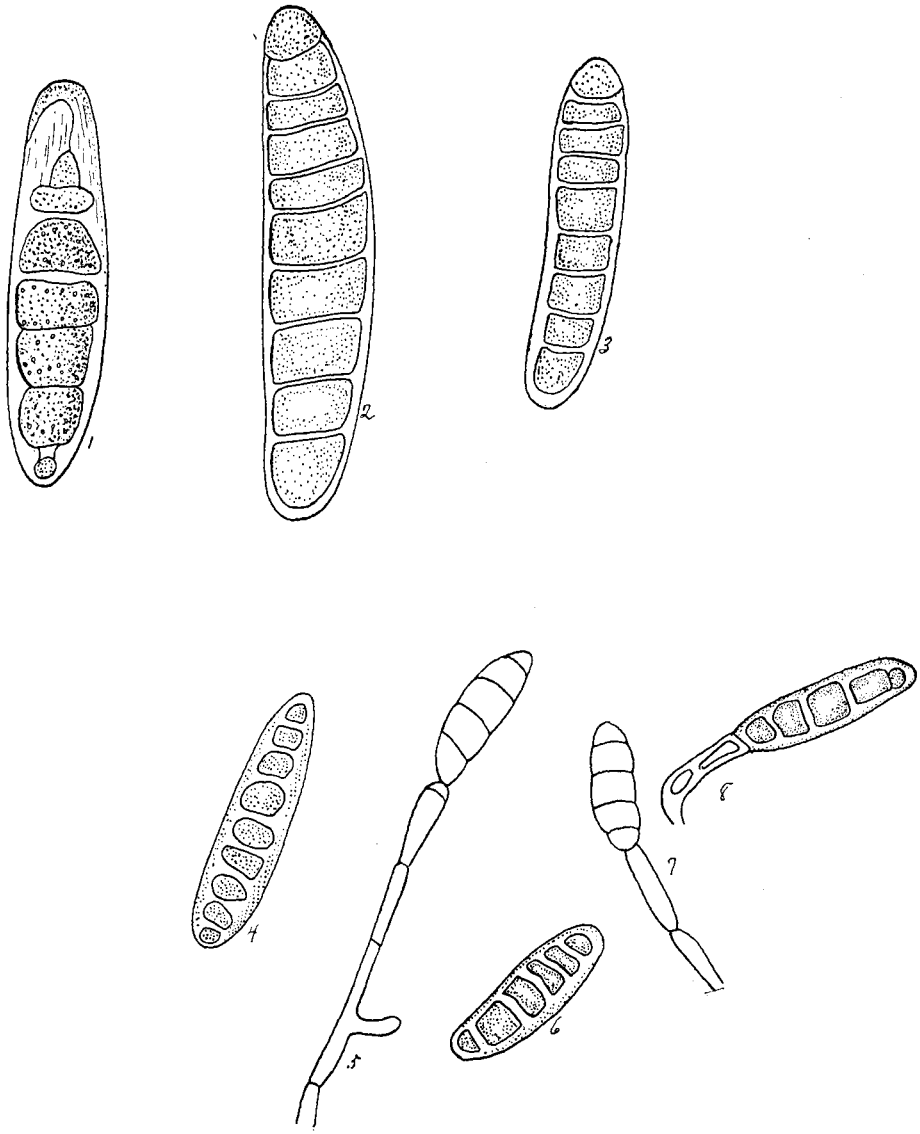


Plate 1

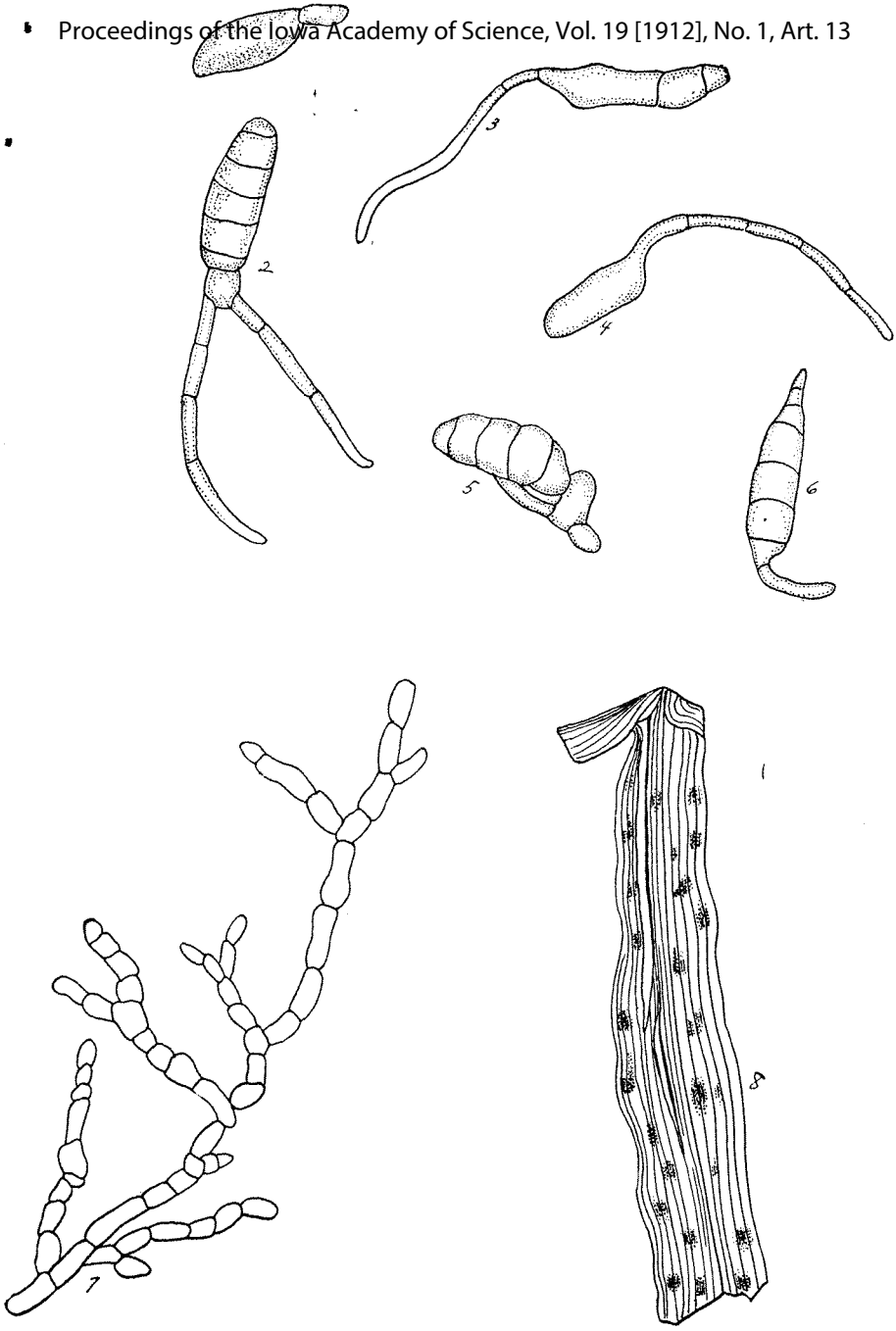
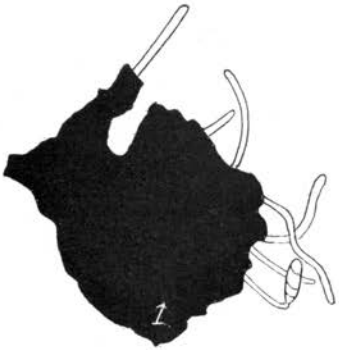


Plate 2



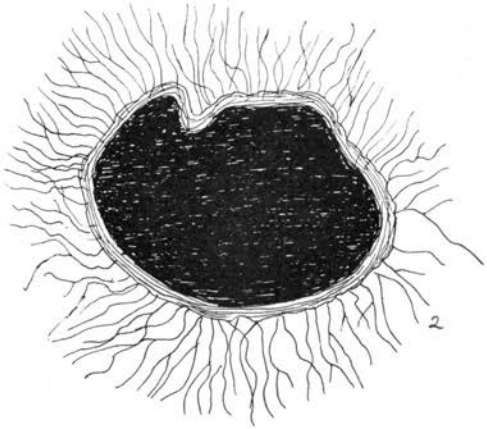


Plate 3