The Dissemination of Disease by Means of the Seed of the Host Plant.

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It has been known for a long time that diseases can be spread by means of the seed of the host plant. As early as 1730 Jethro Tull recommended a change of seed to avoid smut. Since then the list of such diseases has steadily increased until now there is a large number of them.

A knowledge of the method by which infection of the seed takes place and of the subsequent growth of the parasite is of value, since it will reveal a vulnerable point of attack, if there be any, in seeking means of controlling the disease. It is the purpose of this paper to indicate briefly those diseases of cultivated plants which are disseminated by means of the seed of the host plant and to point out the method by which the seed becomes infected.

These diseases can be divided into two classes, those which infest the seed internally, i. e., the organism entering the maturing seed and existing within in a dormant condition until the germination of the seed; and those which infest the seed externally, i. e. the organism or its spores becoming attached to the surface of the seed and entering the host plant at the time it germinates. The diseases belonging to the former class are the Anthracnose of Beans, the Blight of Peas, the Loose Smut of Wheat and Barley, and possibly a few of the Rusts. Under the latter class may be included most of the Smuts, the Wilt of Flax, and probably some of the Rusts and a few Bacterial diseases.

Bean Anthracnose.

Colletotrichum lindemuthianum (Br. & Cav.) on *Phaseolus vulgaris.*

The fungus causing this disease survives the winter in the seed of the host plant. If the affected pods are allowed to ripen on the vines, the mycelium of the fungus penetrates further and further, eventually entering the seeds, usually causing them to become spotted (Figs. 1 and 2). Here

the mycelium remains in a more or less dormant state until conditions are favorable for the germination of the bean seed, when it renews its activity.

An examination of a diseased seed will reveal an abundance of mycelium in the infected portions. By carefully treating the seed with hot water or formalin to rid them of surface fungi and placing them in a sterile moist chamber, one is able to obtain spores in great profusion on the seed before it has germinated and later on the cotyledons, stems and leaves of the seedling in the sunken and discolored cankers caused by the fungus. Dr. Halstead reports that he has found spores of the Anthracnose on the dry beans, especially in the cavity between the cotyledons.[1]

In the germinating plant, no doubt the plumule is often infected by contact with the diseased portions of the cotyledons. (Fig. 3.) Spores, however, are produced upon the cotyledons after the bean has expanded its true leaves and when released by the dissolution of the mucilaginous matrix they are washed to the ground or on the stems below. The stems become infected from these spores and cankers are formed at the infected places. Often these cankers encircle the stem and thus cut off the supply for the leaves above. Sixty-one German Wax Beans apparently healthy were planted in the greenhouse. When well up five were observed which had infected cotyledons, the others appearing healthy. Seventeen days after planting thirty-one of the plants were affected by the disease at the base of their stems, showing, doubtless, that spores from the cotyledons of the five plants had infected the stems of the others. (Fig. 4.)

When the plants are moist the spores of the fungus are in a condition to be easily disseminated, so that working among the plants at this time or otherwise disturbing them aids in the dissemination of the fungus if any diseased plants are present. Even the wind aids dissemination by scattering contaminated drops of water to healthy plants, or by blowing the plants against each other. In this way the disease spreads to the leaves, stems and pods of the plant during the growing season.

The selection of seed from unaffected pods seems at present to be the most satisfactory method to pursue in controlling the disease. The pods should be selected in the field and only such as are perfectly free from all evidence of disease should be selected. Apparently healthy beans within an infected pod may harbor the mycelium of the fungus without showing any evidence of it. Enough seed can be selected in this way to plant small patches. Those who grow large areas should select enough beans to plant

1. Halstead, B. D., The Anthracnose of the Bean. A Remedy Suggested. Ann. Rept. N. J. Agr. Exp. Sta. 1891, p. 284.

half an acre and use the beans from this seed-patch for subsequent plantings. By careful selection after this manner each year the disease can be controlled to a profitable extent.

Sunscald of Pea.

Ascochyta pisi Libert. on *Pisum sativum.*

During the summer of 1907, my attention was called to this disease affecting the garden pea. As observed at this time, the leaves, stems and pods were badly spotted. (Fig. 5.) The spots on the pods were not confined to the surface alone, but in many cases extended entirely through the pod, as was evident from the fact that spots were found exactly opposite those on the other side and the seed between the affected portions was discolored or distinctly spotted by the disease. I gathered a number of the diseased pods of both early and late varieties and planted twenty-three seeds of each variety in the greenhouse during the winter following. Several seeds of the late variety were distinctly spotted. All of the early variety germinated and thirteen of the late variety. Those that did not germinate were found to be decayed. Soon after they came up, nearly all of the plants died. Usually the stem near the base withered and turned brown, resulting in the death of the young plant.

Five of the forty-six planted lived and produced pods. Even the lower leaves of these withered and dropped off, giving the plant a very straggling appearance. No spots such as were observed on the plants grown in the garden were to be seen, contrary to my expectation, but from the description of the disease given by others,[1] the trouble was undoubtedly due to Ascochyta.

Kruger, a German mycologist, found that if diseased seed was soaked in water from forty-eight to seventy-two hours, the mycelium of the fungus would completely encircle it, and grow out into the water, forming a white mass of radiating threads. Van Hook verified this statement and also found that if the diseased pea seed were placed in a germinator for a few days a heavy coat of white mold would be formed about them in which, if seed were removed to a covered dish with less moisture, numerous reddish-brown pycnidia would be formed.[2] These pycnidia were produced by the mycelium of the fungus which had lain dormant in the seed since its maturity. When the conditions were right for the germination of the seed the fungus renewed its growth. The mycelium grows within the stem con-

1. H. G. Howell, J. M. Van Hook.
2. Van Hook, J. M., Blighting of Field and Garden Peas. Ohio Bul. 173, 1906.

currently with the growth of the plant, causing lesions at its base and a withering of its lower leaves, and often its death before or soon after its appearance. Probably the embryo is affected by the fungus in most cases where the seeds do not germinate. The spores exuded from the lesions on the stems, leaves and pods are scattered by the wind and other agents, and infect healthy plants. If the spotted pods are left upon the vines until the seeds are mature the mycelium penetrates some of these seeds, which thus carry the fungus over the winter, making this an important means for the dissemination of the parasite.

Seed treatment has not been very effective in controlling this disease which, fortunately, with the exception of an occasional epidemic, is not very destructive. Rotation of crops is one method usually recommended.

Loose Smut of Wheat.

Ustilago tritici (Per.) Jens. on *Triticum vulgare.*

It was formerly thought that the spores of this fungus became attached to the coat of the healthy seed and germinated at the time of the germination of the seed, infection threads from the promycele penetrating the first leaf-sheath, as is the case with stinking smut. But later investigations have made quite certain that the germinating spore infects the pistil of the healthy wheat at flowering time, the mycelium establishing itself within the ovary during its development and remaining dormant in the ripened seed until it had germinated, the mycelium then continuing its own development.[1] This fact explains why the results of seed treatment for this species have been negative to so large a degree.

During the latter part of June, 1907, I inoculated many wheat plants with the spores of U. tritici by dusting the young stigma with the spores. The stigma seemed to be most receptive when quite young. Records of inoculations were kept and heads gathered at varying intervals of time from date of inoculation. A pistil examined one day after inoculation showed that a number of spores adhered to the stigmas and that several had germinated. It was hoped that the point of infection would be observed and although the germ tubes of spores were seen directed toward the interior of the stigma, none were seen entering or within. Spores were also germinating on the surface of the ovary and it may be that the point of entrance is through the ovary coat. Of those seeds which were

1. Brefield and Falck, K., Flower Infection by Smuts. Untersuch. ges. Gebiet Mykol. 1905, No. 13. Abs. in Bot. Centbl. 101 (1906) No. 8: 212–213.

allowed to mature after being inoculated, thirty were planted in a box in the greenhouse on October 10th, 1907. On the 15th of May, 1908, the resulting wheat-plants had begun to head out. All the heads were more or less smutty. The majority of them were reduced to a mass of spores as is commonly observed in the field. In a few cases the ovary was the only part entirely destroyed, the outer portion being unaffected or only streaked with sori containing the spores. As the wheat plant develops the mycelium of the fungus grows upward probably much after the manner of the mycelium of the stinking smut. It enters the young head early in its formation and branches into numerous sporogenous hyphae, which completely destroy the pistil and other parts of the flower. These hyphae divide into a number of cells within each of which a chlamydospore is formed as in Oat Smut. The walls of the hyphae become gelatinous and later disappear, leaving the spores free. These dry on exposure to the air, forming a dusty mass so commonly observed at the flowering time of wheat. These spores are blown about by the wind and infect the ovaries of healthy heads, thus establishing the fungus for another year. (Fig. 6.)

Naked Smut of Barley.

Ustilago nuda (Jens.) Kell. and Sw. on *Hordeum vulgare.*

This Smut is similar in methods of attack and in field characteristics to the Loose Smut of wheat. The head is reduced to a mass of spores which are scattered at the flowering time of barley. These spores infect the ovaries of the healthy plants in which the mycelium of the fungus develops until the seed is ripe, remaining throughout the winter in a dormant condition and continuing its growth concurrently with the growth of wheat after seed is planted.

The Stinking Smut of Wheat.

Tilletia foetens (B., & C.) Trelease and *T. Tritici* (Bjerk.) Wint. on *Triticum vulgare.*

Tilletia foetens has a spore with a perfectly smooth coat, while the epispore of *T. tritici* is much reticulated. Their method of infection and growth are similar.

The spores of these two smuts are scattered about at harvesting time or in some other way become attached to the healthy seed. When placed in a situation favorable for their germination they send out a short, thick promycelium and at its tip is borne a cluster of slender tapering sporidia

which conjugate in pairs. Infection threads are either produced by these sporidia capable of penetrating the host plant or, as is usually the case, secondary sickle-shaped sporidia are borne on short filaments and these sporidia produce infection threads. The formation of sporidia greatly increases the chances of the fungus to infect the host.

The infection of the wheat plant takes place soon after the germination of the grain and even before the first leaves are put forth. Hoffman believed that the infection threads can enter only the sheathing primary leaf or the collar between the root and stem while they are yet very young and delicate and concludes that anything which would hasten the growth of the young plant would tend to lessen the chances of infection.[1] Bolley believes that infection does not take place unless there is a large number of sporidia in close contact with the seedling during the infection period.[2] The mycelium after gaining entrance to the young plant pushes its way upward with the growth of the host, the older mycelium dying and its contents passing upward into the young advancing ends, and finally fruits in the ovaries by the production of chlamydospores from sporogenous hyphae that have developed abundantly in them. The Stinking Smut differs from the Loose Smut of Wheat in that the destruction is entirely confined to the ovary contents. The ovary coat is left intact, so that one would easily fail to recognize any infection unless he made particular observation or noticed the disagreeable odor characteristic of the fungus. The affected kernels are somewhat larger than healthy ones and this increase in size causes the florets to spread, making the head more open than a healthy one. When the kernels are cut open they are found to be filled with a mass of olive-brown spores of a greasy character.

The Loose Smut of Oats.

Ustilago avenae (Pers.) Jens. and

The Hidden Smut of Oats

Ustilago levis (Kell. & Sw.) Magnus on *Avena sativa.*

There are two distinctive species of oat smut called respectively the Loose and the Hidden Smut of Oats. Both are much alike in their methods of development and both succumb to the same method of treatment. *Ustilago avenae* is by far the commoner and is the one which causes the

1. Note from Kellerman and Swingle, Report on the Loose Smut of Cereals. 2d Ann. Rept. Kan. Exp Sta. 1889. pp. 213-238.

2. Bolley, H. L., New Studies upon the Smuts of Wheat, Oats and Barley N. Dak. Bul. 27, 1897.

greatest damage of all grain smuts in the United States. The disease makes its appearance at the time of blossoming of the oat-plant, the whole head becoming a dusty olive-brown mass. The infected flowers are entirely destroyed by the disease and even the awns are affected. In the Hidden Smut the spore mass is more or less concealed by an outer membrane of the floral parts that remain intact from the disease. The dusty mass is made up of great numbers of spores which are blown about by the wind, some being caught in the open glumes of flowering oat-plants. Since after blossoming the glumes close tightly about the ovary, such spores are held imprisoned and remain so until the seed is in a condition to germinate. Then the imprisoned spores germinate after the manner of several smuts, producing a three or four-septate promycelium, which usually bears oval or elliptical sporidia at the apex or laterally at the septa. Infection threads are usually produced by these sporidia, but the promycelial threads may also produce them. These infection threads gain entrance to the host by piercing the delicate young cells of the first leaf-sheath before the leaf has appeared. Plants are free from infection after the growing leaves have pushed themselves as much as one c. m. through the leaf-sheath. Brefield found by experimentation that oats germinated up to 15° C. gave 3 per cent. smutted heads, but when grown at a higher temperature give 1 to 2 per cent. smutted heads or more.[1] This bears out ordinary experience that late sown oats while more liable to rust are freer from smut. This immunity is probably due to the short period when the plant is open to infection as a result of the rapid germination and growth of the seed in the more favorable condition of temperature.

In from thirty-six to forty-eight hours after infection considerable mycelium will be developed which penetrates the first and second leaves and gains entrance to the stalk or culm. It grows upward and invades the young head in quite the same manner as in case of other smuts. In place of a healthy head, a dusty mass of spores appears, which are scattered to healthy heads by the wind.

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1. Brefield, O., Recent Investigations of Smut Fungi and Smut Diseases. Trans by Erwin F. Smith, Jour. Mycol. VI, pp. 1-8; 58-71; 153-164. 1890-91.

Covered Smut of Barley.

On *Hordeum vulgare.*

Ustilago hordei (Pers.) Kell. & Sw.

This smut differs from *Ustilago nuda* in its method of infection and in its appearance in the field. The floral parts are not as completely destroyed and these serve to confine the spore mass and thus keep the spores from escaping until threshing time. Although they have a smooth epispore they cling to the seed and germinate with it, producing sporidia in abundance, laterally and terminally, upon a two to three-septate and elongated promycelium. These sporidia send out infection threads which penetrate the host in its early stage of growth. The swollen segments of isolated promycelium may also produce infection threads. The manner of growth in the host and the production of chlamydospores is similar to that of other loose smut.[1], [2]

Other Smuts Carried Over by the Seed of Their Host Plants.

Grain Smut of Rice.

Tilletia horrida Tak. on *Oryza sativa.*

Head Smut of Sorghum.

Spacelotheca Reitiana (Kuhn) Clint. on *Sorghum vulgaris.*

Grain Smut of Sorghum.

Spacelotheca sorghi (LK.) Clint. on *Sorghum vulgaris.*

Grain Smut of Hungarian Grass.

Ustilago crameri Kom. on *Setaria italica.*

Leaf Smut of Timothy, Red-top, Blue-grass, and other Grasses.

Ustilago striaeformis (West.) Miessl.

Smut of Tall Oat Grass.

Ustilago perennans Rostr. on *Arrenatherum avenaceum.*

And smuts of many wild grasses.

Flax Wilt.

Fusarium lini Bol. on *Linum usitatissimum* and *L. humila.*

The spores of this fungus become attached to the seed and germinate with it in the soil. These infect the roots of the young plant, often killing the seedling before it appears above ground. In case when plants live and

1. Clinton, G. P., Smuts of Illinois Agricultural Plants. Ill. Bul. 57, 1900.
2. Kellerman & Swingle, Reports on the Loose Smut of Cereals. 2d Ann. Rept. Kan. Exp. Sta., pp. 313-288 : 1889.

are able to mature their seeds, they are frequently internally infected by the mycelium of the fungus and thus serve to carry the disease from season to season.[1], [2], [3]

Rusts.

It is now believed by some pathologists that certain species of Puccinia are perpetuated by means of the seed of the host plant. Eriksson, after long investigation, came to believe that the fungus exists in the seed in a mycoplasmic form which can only with difficulty be detected from the protoplasm of the cells in the seed. As the plant grows, the mycoplasm spreads from cell to cell, finally appearing as mycelium in the intercellular spaces. He believes that the rust may be inherited from preceding crops by means of this mycoplasm.[4] It is generally believed that the facts do not warrant the acceptance of this theory. Bolley thinks that infection may take place from spores inside the seed itself. He found both uredo and teleutospores of Puccinia graminis borne in spore beds just below the bran layer of wheat and also found plenty of rust-mycelium within the seed.[5] Eriksson reports seed infection with Puccinia graminis and P. glumarum in wheat, oats, and barley, and P. dispersa on rye. Noack reports a case from Cooke of carnations being affected by rust which must have been caused by seed infection and he himself observed an incident of celery-rust that was likewise caused by infection from the seed.[6]

Anthracnose of Tomato.

Colletotrichum lycopercici Ches. on *Lycopersicum esculentum.*[7]

Bacteriosis, or Bacterial Blight of Beans.

Bacterium phaseoli Sm. on *Phaseolus vulgare.*[8]

This disease affects the stems, leaves, and pods (Fig. 7) of various field and garden beans, including limas. It spreads through the pods into the seeds, where the bacteria live through the winter, thus carrying the disease from season to season.

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1. Bolley, H. L., Flax Wilt and Flax Sick Soils. N. D. Bul. 50, 1901.
2. Bolley, H. L., Flax and Flax Seed Selection. N. D. Bul. 55, 1903.
3. Bolley, H. L., Flax Culture. N. D. Bul. 71, 1906.
4. Eriksson, J., A General Review of the Principal Results of Swedish Research on Grain Rusts. Bot. Gaz. XXV; 26; 1898.
5. Bolley & Pritchard, Rust Problems, etc. N. D. Bul. 68: 1906.
6. Noack, Fritz, Die Verschlepping von Pflanzenkrankheiten durch Sämereien. Zeitsch. land. u. ver Hersen, 1893, No. 20, pp. 161-2. Trans. by Prof. H. H. Whetzel.
7. Harvey, F. L., Tomato Anthracnose. Me. State Coll. Ann. Rept. 1893. Part II, p. 152.
8. Whetzel, H. H., Some Diseases of Beans. Cor. Exp. Sta. Bul. 239, 1906.

Black Rot of Cabbage.

Baccillus campestre (Pam.) Sm. on *Brassica oleracea* and *B. campestris.*

Infection takes place through the water pores of the leaves. The margins become affected and later the whole leaf withers and dies from thrombosis, i. e. by the plugging up of the xylem vessels by the bacilli. It has been shown while the bacilli will die when exposed from 8-10 days on a dry cover glass, they are able to live ten to thirteen months on the smooth surface of a cabbage seed, and that they often pass the winter in such a position.[1]

Stewart's Sweet Corn Disease.

Bacterium stewartii. Sm. on *Zea Mais.*

This is a thrombotic disease of sweet corn that is believed to be disseminated from year to year chiefly by means of bacteria clinging to the seed.[2]

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1. Harding, H. A. / Stewart, F. C. / Prucha, M. J. — Vitality of the Cabbage Black Rot Germ on Cabbage Seed. N. Y. Exp. Sta. Bul. 251, 1904.
2. Stewart, F. C., A Bacterial Disease of Sweet Corn. N. Y. Exp. Sta. Bul. 139, 1897.

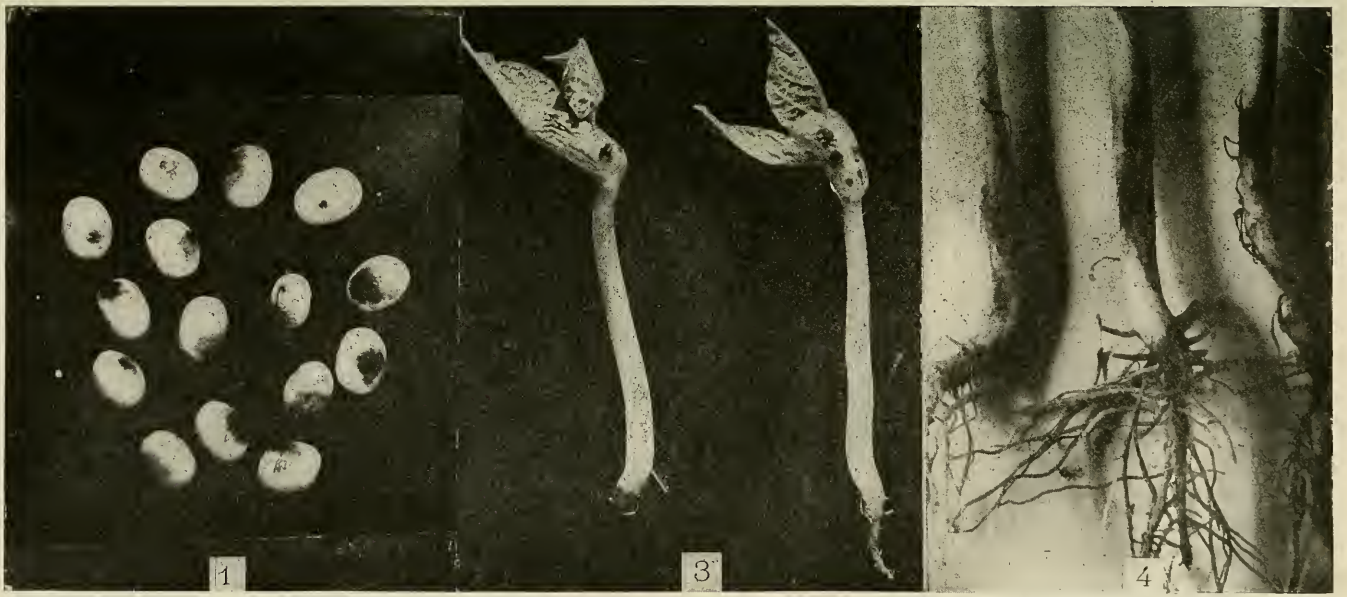

Fig. 1. Bean seed spotted with Anthracnose.

Fig. 3. Seedling bean plants showing Anthracnose spots on the cotyledons.

Fig. 4. The lower portion of stems of bean plants affected with Anthracnose, showing lesions near the base.

Fig. 5. Pea pods affected with *Ascochyta pisi*.

Fig. 2. Bean pod with canker cut away so as to show that the fungus had penetrated the seed.

Fig. 6. Heads of wheat affected with the Loose Smut.

Fig. 7. Bean pods spotted with Bacterial Blight.