New York Agricultural Experiment Station.

PETER COLLIER, DIRECTOR.

BULLETIN No. 48—NEW SERIES.

DECEMBER, 1892.

SOME BEAN DISEASES.

GENEVA, N. Y.

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*Connected with Fertilizer Control

BULLETIN NO. 48.—NEW SERIES.

OUTLINE OF CONTENTS.

BEAN ANTHRACNOSE AND ITS TREATMENT.

Popular Discussion.

Bean Anthracnose is a disease which sometimes causes very serious loss to bean growers, whether market-gardeners, truck-farmers, or farmers, and in New York state it frequently, if not usually, diminishes by a good percentage the profits of the crop. It has also been reported as prevalent in various other parts of America and in Europe.

Some New York farmers have attributed the loss of nearly their entire crop the past season to Anthracnose, and this estimate was made after they were furnished with a sample of the disease as it appears on the pods, in order that the report might be made as accurate as possible. Many, on the other hand, reported loss varying from five per cent. to twenty per cent. A smaller number gave estimates of loss varying from twenty-five per cent. to nearly one hundred per cent., and others reported no loss at all.

As noted in the last report of the Director of this Station,* nearly one-half the dry beans produced in the United States are raised in New York state. Those counties in which the crop exceeded 20,000 bushels in 1880 are named below in order of the rank of their yield, Monroe county heading the list with a yield of 293,563 bushels. California was the only state except New York which exceeded the yield of this one county. The following is the list: Monroe, Orleans, Livingston, Genesee, Wyoming, Niagara, Wayne, Jefferson, Clinton, Ontario.

According to the 1890 Census Report of the acreage of beans† on the seed farms of the country, New York state heads the list with 4,600 acres, or thirty-six per cent. of the whole, a greater acreage than all the rest of the United States combined, excepting Illinois and Michigan.

In the acreage devoted to snap or string beans on truck-farms,

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*Tenth Annual Report N. Y. Experiment Station, p. 23.

† Except Lima beans.

the "New York and Philadelphia" district stands second only to the "South Atlantic" district. The statistics of the acreage devoted by market-gardeners to snap beans are not at hand, but it is known that snap beans are with them an important crop. On the whole it may be said that the bean crop of New York state is of sufficient importance to justify a study of bean diseases.

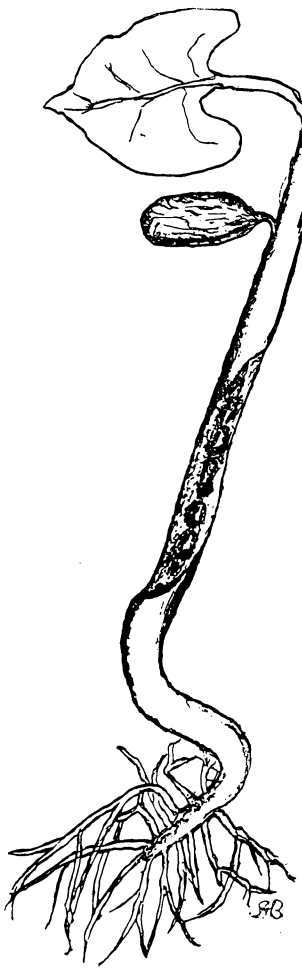
It is readily seen that a loss of five per cent. of the crop means a loss of more than five per cent. of the profits, and, whether the crop be small or large, an injury amounting to five per cent. of the yield is of sufficient importance to justify an inquiry as to its cause and remedy. Especially is this true when an injury results from a disease capable of propagating itself from year to year in the diseased seed, and one that under favorable conditions for its development may raise the loss from five per cent. to fifty or seventy-five per cent., or perhaps entirely ruin the crop.

Such a disease is the Bean Anthracnose, frequently but incorrectly called Bean Rust. The latter name should be reserved for the true Bean Rust, which is quite a different, and, so far as the writer's observation goes, much less troublesome disease of beans. Again, much of the loss popularly attributed to Rust is really due to a bacterial disease which blights the foliage and causes watery spots on the green pods, followed frequently by decay. Sometimes it is even more destructive than the Anthracnose. Frequently the Anthracnose and this Blight are present on the same plant and even on the same leaf or pod.

It is well at the outset to have these distinctions clearly in mind, for the following discussion is devoted first to but one of these diseases, namely, the Anthracnose, and afterwards the Blight and Rust are given brief consideration. With the aid of the following descriptions of the way this disease affects the different parts of the plant, together with the accompanying illustrations, it is hoped that the careful reader will find no trouble in recognizing Bean Anthracnose.

Diseased Seed. When Anthracnose infected seed is planted the disease most frequently is found on the seed leaves (cotyledons) as soon as they push through the surface of the soil, but it may be found on any other part of the plant above the roots. Sometimes it eats through the main stalk and in that way destroys the young plant, or it may kill it before it is able to lift itself through

the surface of the soil. By killing the young seedlings and the germinating seed a good stand of beans is prevented sometimes causing a loss of twenty-five per cent. of the seed planted. Dr. Halsted* reports a loss of fifty per cent. on seed grown indoors in boxes. With such seed planted in the field even a greater loss might occur. Fig. 1 from a sketch of a diseased seedling shows



the pits on the seed leaves and along the stem. The stem is nearly eaten through by the disease.

APPEARANCE ON YOUNG PLANTS. With those plants which succeed in outgrowing its early attacks, the disease continues its depredations on stems and foliage. Very often it eats off the stalklet of a leaflet at the joint where it is attached to the main leaf stalk (petiole), and frequently it drops the whole leaf by eating through the petiole at the joint near the base of the leaf.

*Annual Report of New Jersey Experiment Station, p. 285.

APPEARANCE ON LEAVES. Fig. 2 from a photograph shows the appearance of the disease on the underside of a leaf. It causes the veins to become black and shriveled, and in the softer tissue it forms dark spots. It seems to show a fondness for the veins of the leaf and for the fiber bundles of the plant. These are blackened by its attacks. One of its most characteristic appearances is seen in the dark colored veins and veinlets on the under side of the leaf. It may also become established in the soft green substance of the leaf (parenchyma) between the veins where it usually forms narrow, elongated, dark colored patches that soon break away and leave irregular cracks in the leaf with blackened edges.

APPEARANCE ON PODS. The appearance of the diseased spots on the pods is well shown in Fig. 2. On the sides of the pods, or of the tender young stems, it is readily recognized by the black pits with red borders. At first these are usually circular, but afterwards may become more irregular in outline, sometimes by coalescence forming very large patches. Along the edges of the pods it is seen in narrow strips of dark color. The pits above mentioned are commonly bordered by a narrow reddish discoloration between the diseased portion and the healthy green tissue of the pod.

APPEARANCE OF SPORE MASSES. Soon after the formation of a spot, there appears in the central portion of the diseased area pinkish white dots about the size of pin points. These dots are caused by exudations from the tissues which the fungus has filled with its black threads, and they consist of spore masses, that is to say, the spores which the fungus has produced to spread the disease are here pushed forth in masses. These are also well illustrated in Fig. 2. The spores are held together in masses this way by some substance which readily dissolves in rain or dew, after which they may be scattered to other plants by winds, insects or passing animals. This provision of the fungus for spreading its germs to other plants seems to afford a reasonable explanation for the opinions held by many farmers, that the disease does most damage in damp locations, and that cultivation when the plants are wet with rain or dew is apt to spread the disease more rapidly. The spores are produced by the Anthracnose on whatever part of the plant it may happen to be living, but

probably are formed in greatest abundance on the succulent tissues of the pod.

In the Anthracnose the bean plant has a powerful and persistent foe. If present in the seed it attacks the young plant from the moment it starts to germinate and keeps up the warfare until it has succeeded in establishing itself in the seed again ready for another season's campaign. By injuring the foliage it weakens the plant so that it lessens the yield in this way, and also by its attacks on the pod prevents them from filling perfectly, if at all. On the seed it causes specks, pits, wrinkles or blisters, and all degrees of discoloration. Sometimes the discoloration is so faint as to be scarcely noticeable. As demonstrated by Dr. Halsted, and abundantly confirmed at this station, these infected beans carry the disease from one season to another.

Experiments in Treating Bean Anthracnose.

By means of laboratory, greenhouse and field experiments, investigations have been conducted for the purpose of learning whether Bean Anthracnose could be in any way prevented. These investigations have included the following experiments:

1. Preliminary greenhouse experiments in treating diseased seed with the following fungicides; namely, Hot Water, Ammoniacal Solution of Copper Carbonate and Bordeaux Mixture. The seed was soaked in these fungicides; before planting and the effect of the treatments on the disease carefully noted.

2. Field experiments with seed soaked in the following fungicides; namely, Hot water, Copper Sulphate, Iron Sulphate (Copperas), Mercuric Bichloride (Corrosive Sublimate).

3. Comparison of plants grown from diseased seed with plants grown from healthy seed.

4. Treatment of plants from diseased seed by spraying different lots with Bordeaux Mixture, Cupric Polysulphide and Cupric Borate respectively. At the suggestion of D. G. Fairchild the two latter mixtures were tested and soap was added to all three substances.

It will be noticed that these investigations have proceeded on three separate lines, namely:

a. Treatment of diseased seed.

b. Comparison of yield from healthy seed with yield from diseased seed.

c. Spraying diseased plants.

TREATMENT OF DISEASED SEED. The treatment of diseased seed will be discussed more fully hereafter. It may be simply stated here that the total yield of marketable beans from areas planted with treated seed was in every case less than the yield of marketable beans from equal areas planted with untreated seed. At present therefore this method cannot be recommended. See "Seed Soaked in Fungicides," p. 19 et. seq.

COMPARISON OF YIELD FROM HEALTHY SEED WITH YIELD FROM DISEASED SEED. As to the second line of investigation it may be said that the selection of clean seed is the most important and effective known method of securing healthy plants. It ought never to be neglected with the hope of controlling the disease by means of fungicides, first, because treatment with fungicides cannot completely check the disease after it has once gained a foothold in the field nor can it restore the dead; second, because a good stand of plants cannot be confidently expected from diseased seed.

It is true that in the experiments here reported, the plants treated with Bordeaux mixture gave cleaner and larger yield than those from healthy seed, notwithstanding the fact that the Bordeaux-treated plants came from diseased seed, that is to say, from seed selected because it was diseased. This may be accounted for in two ways: first, the healthy seed was planted just as selected by ordinary care and when germinated showed at once a few plants spotted with the disease, and these diseased plants were purposely allowed to remain mixed with the healthy plants to see what difference would appear between the crop from diseased and from healthy seed as selected with ordinary care: second, the diseased seed was planted adjacent to the healthy seed. Here then were two sources of infection for the healthy plants, namely, from a few diseased plants in their own ranks and from the many diseased plants in neighboring rows. The result was that as the season advanced the healthy plants became more and more diseased till finally in yield and vigor they dropped behind the diseased plants treated with Bordeaux mixture. Had the healthy seed been sorted again carefully before planting, had the crop been

planted by itself, and had every diseased plant been rooted out and carried from the field immediately after the plants showed themselves above ground, there is every reason to believe that the crop would have been larger and the beans cleaner than they were under the "ordinary care" method. The data which justifies this opinion is given more fully hereafter. See "Selection of Healthy Seed," p. 23.

Where the seed can be secured from a field known to be free from the disease it is advisable to do so. If, however, the only seed available contains diseased beans, the sound ones only should be used for planting. All wrinkled, blistered, spotted beans or those with sunken pits or with any discolorations whatever, should be rejected. From a badly diseased lot of seed a rigid selection may secure but a small per cent. of sound seed as was the case with the yield from a badly diseased row in one of the experimental plots the past season. Ninety per cent. of the entire yield was marketable, but only one per cent. was fit for seed. If, however, anyone knowing the life history of the disease is content to plant infected seed, surely there is no ground for complaint if he reaps what he has sown.

By means of the following tables the yield of the crop grown from healthy seed may be compared with the yield from an equal area planted with diseased seed and with a third equal area which was planted with diseased seed and the plants sprayed with Bordeaux mixture. In column I is given a comparison of the yield of pods counting the total yield of plants from healthy seed as 100. In column II a similar comparison of the weight of the total yield is given. The yield of the plants early in the season is compared on p. 26.

	Yield by number of pods.	Yield by weight of pods.
	I	II
Healthy Seed..... ..	100	100
Diseased Seed.....	90	83
Bordeaux Mixture.....	115	123

SPRAYING DISEASED PLANTS. Spraying plants with weak Bordeaux mixture gave the best results of any treatment with fungicides tested. The formula used was two pounds of copper sulphate and one and one-third pounds of freshly slaked lime to

thirty gallons of water, and enough soap to make a suds. The object of adding the soap is to cause the mixture when applied in a fine spray to form a thin film or coating over the entire surface of the leaf instead of standing in separate, even though minute, drops. If soap is not used it would probably be best to use less water with the weight of copper and lime above given, taking rather from twenty-one to twenty-six gallons of water for the given amount of the other ingredients.

The first spraying was given fourteen days after planting. At this time very few plants had expanded the third leaf. The withering distorted foliage and the black pits on stem and seed leaves (cotyledons,) showed that the disease was actively at work. Care was taken to cover every part of every plant with the spray since the object of the spray is not to kill the fungus in the affected plant but to prevent its spreading to healthy foliage and infecting the new leaves. Any application which would succeed in killing the fungus in a diseased plant would also kill the plant.

After an interval of nine days the beans were sprayed again; the third treatment followed the second at an interval of twenty-three days; and finally after another interval of eighteen days a fourth treatment was made. No unyielding rule for the number or frequency of treatments can be given. If rains are abundant, and the fungicide is washed off from the leaves, the foliage must again be covered with the spray in order to ward off the disease. On the other hand should pleasant weather prevail, and the fungicide remain on the foliage, it will not be necessary to spray again until sufficient new foilage has grown out to justify another treatment. With field beans three sprayings may prove sufficient, but probably snap or string beans can profitably be given four treatments, but, as before stated, no invariable rule can be given. In the following table a comparison is made of the yield of plants treated with the different fungicides, counting the yield of the Bordeaux-sprayed plants at 100. The amount of damage from Anthracnose is deducted in each case. In column I the yield is computed from the total number of pods produced, and column II gives the yield by weight of the total number of pods.

	I. Yield by number of pods.	II. Yield by weight of pods.
Cupric Borate	56	40
Untreated	64	51
Cupric Polysulphide	71	54
Untreated	61	57
Bordeaux Mixture	100	100
Untreated	61	51

For the benefit of those who may be interested in the details of the experiments and a description of the microscopic character of the fungus which causes Bean Anthracnose, a more extended account is appended below.

In conclusion the following treatment for Bean Anthracnose is recommended:

1. *Selection of sound seed for planting.*
2. *Immediate removal of infected seedlings from the field.*
3. *Keeping the foliage covered with Bordeaux Mixture.*

The first recommendation can well be followed out during leisure hours between harvest and planting time. It will probably accomplish as much as two good sprayings, and we have no doubt that time spent in selecting seed is very profitably employed.

The second recommendation should be carried out thoroughly. To pull out the plants and leave them on the ground is not sufficient, for on the uprooted plants the fungus will quickly ripen its spores and will live long after the plant is dead.

Many object to the use of Bordeaux mixture because they experience so much trouble in preparing and applying it. Preparation of Bordeaux mixture may be simplified by a test which obviates the necessity of weighing the lime, and, where large quantities of lime are used, permits slacking the lime in large quantities at one operation. The copper sulphate is weighed and mixed with an amount of water sufficient to dissolve it. When it is completely dissolved, the lime, in the form of thin whitewash, is strained through burlap (gunny sacking) into the copper sulphate solution. A drop or two of potassium ferrocyanide (saturated aqueous solution) added from time to time after thoroughly stirring the mixture will show when enough lime has been added to form the Bordeaux mixture. If not enough lime has been used, the drop of ferrocyanide will turn to a very dark color the moment it

touches the mixture ; if enough lime has been used, the ferrocyanide will not change color when it is dropped into the mixture. Water is then added till the Bordeaux mixture is diluted to the desired strength. The commercial form of potassium ferrocyanide may be used for this test. A supply for the entire season may be purchased for a few cents.

When Bordeaux Mixture is applied with a knapsack pump the motion of the body will keep the mixture well stirred, but when a barrel-pump is used, the motion of the cart is not sufficient to prevent the copper compounds from settling to the bottom. When this occurs, part of the mixture is applied in a very weak form and a part has an excessive amount of copper. Finally when the sediment is discharged it often clogs the nozzle and causes much trouble. These difficulties are best overcome by arranging some kind of dash or agitator so that with every stroke of the pump the whole mixture is thoroughly stirred. An agitator is even more necessary for the application of Paris green than for Bordeaux Mixture. Some manufacturers now supply large pumps with agitators.

The true Improved Vermorel nozzle is considered best for applying the Bordeaux mixture, better than the modifications of it which are sometimes offered. Success in treating the Anthracnose as above recommended depends very much upon the kind of nozzle used and the care taken to cover all parts of the plants with the spray.

Spread of Disease on Gathered Pods. Experiments with gathered pods of snap beans from diseased plants proved beyond question that pods which were apparently perfectly sound and without a blemish when first gathered may become badly spotted in two or three days' time. It was also proven by inoculation that unblemished pods may soon become infected by spores from diseased pods. It was very easy to see that shipments of snap beans gathered from diseased plants might be sent from the producer in apparently good condition and yet become very badly spotted by the time they reach the consumer.

Discussion of the Fungus and Details of Experiments.

Bean Anthracnose is so named because of the sunken spots or "ulcers" formed by the disease on the pods or other succulent tissue. It is due to a parasitic fungus known as *Colletotrichum Lindemuthianum*, (Sacc. and Magn.), Briosi and Cavara, but was formerly known as *Glœosporium Lindemuthianum*, Sacc. and Magn. It is found on various varieties both of bush and pole beans of the species *Phaseolus vulgaris*, L., and is not confined to wax and butter beans. In an article on *Glœosporium Lindemuthianum* published in the Department of Agriculture Report 1887, page 361, it is stated that "It is the pods and the beans they contain that are chiefly affected, the other parts of the plant being rarely if ever attacked. Frank attempted to infect the leaves and stems but with no result. He also tried to infect different plants but failed." During the past season we have frequently found the fungus fruiting on stems and leaves and have seen plants killed by the disease not only before they had produced any pods but even before they had blossomed. Early in the season there have been found rows of beans with every plant infested with Anthracnose. In 1891 Dr. Halsted* showed that the disease may be carried over winter in infected seed and that the disease frequently appears on the stems and cotyledons of plants grown from such seed. He also succeeded in infecting the leaves and in transferring the disease to healthy bean plants. The results he obtained have found abundant confirmation in the work at this station during the past season.

Microscopic Characters. The microscopic characters of this fungus may be briefly given as follows:

The mycelium may be hyaline or nearly so, but just beneath the epidermis it forms a dense, dark-colored stroma, which precedes the production of spores. From this stroma arise the dense clusters of basidia that at first lift the unbroken epidermis and form dark dots or pimples (acervuli) visible to the naked eye, on the diseased surface. On the extremities of the basidia spores

*Annual Report N. J. Exper. Station, 1861, page 284.

are produced, and finally pale pinkish colored masses of them about the size of pin points burst the epidermis as shown on the diseased spots of the pods in Fig. 2. Sometimes neither the blackened color of the stroma nor the pink tint of the spore masses is noticeable, but such exceptions are infrequent. Grown on sterilized potato plugs in test tube cultures the spore masses were nearly colorless and showed no pink tint. The mycelium is septate, branched and of variable diameter. According to Frank* the spores fall on the surface of the host and send out a germ tube which presses its enlarged end closely against the epidermal cells. From this a colorless hypha penetrates the cell walls and grows into a mycelium which fills the cell cavities. Then the mycelium penetrates into the underlying tissues.† "Almost immediately the cell walls of the host and their contents become discolored and in the exocarp the cell walls collapse, thus forming an almost solid mass of cell walls and mycelium." Fig. 3 illustrates a section of the pod through the collapsed tissue which underlies a cluster of basidia. The epidermis which formerly covered the acervulus has broken away and a portion of its recurved edge is seen at the left. A seta is also shown projecting beyond the acervulus, and a few spores remain attached to the ends of the basidia. The collapsed tissue is seen below. By the collapse of the tissues the Anthracnose pits are formed. In the leaf parenchyma, as previously stated, the tissue becomes collapsed and brittle, so that rifts through the leaf soon form in the center of diseased spots.

The basadia are upright (perpendicular to the stroma) and unbranched. Associated with them are a few setæ which when mature are long and of dark brown color. Sometimes the setæ are septate and sometimes they arise from a many-celled bulbous base.

The conidia are illustrated in Fig. 4. They vary in length from 11.5μ to 18μ and in diameter from 3.7μ to 5.3μ. An average of sixteen measurements gave the following dimensions: 15.2μ x 4.4μ. They are non-septate, hyaline, oblong, cylindrical or some-

*Deutschen Botanischen Gesellschaft, Berichte der, Band 1, 1883, pp. 31–34.

†U. S. Dept. Agr. Report 1887, p. 363.

times slightly narrowed towards one end. They burst through the epidermis in masses held together by some substance which soon dissolves in water.

The fresh conidia may be germinated readily in sterilized broth made from bean pods or foliage. They germinate less readily in sterilized water. Germination usually begins at or near the extremities of the spore, and two or more germ tubes may issue from one spore. Fig. 5 illustrates the progress of germination about twenty-four hours after the spores were put into bean broth. At this stage some of the hyphæ were already septate and branched. The appearance of the hyphæ seemed to be influenced somewhat by the media in which they were grown.

PREVALENCE IN WESTERN NEW YORK. Reports as to the prevalence of Bean Anthracnose have been received from fifty-seven farmers representing nearly every county in Western New York. When the letters of inquiry were sent out, a sample Anthracnosed pod was inclosed, that there might be no misunderstanding as to the particular disease which was being investigated. Though these reports are few in number yet they throw some light on the importance of finding a remedy for the disease, since in several instances the apparent loss from this trouble was very great.

Of the fifty-eight reports above mentioned, thirty-six (62 per cent.) reported the disease, two were doubtful as to its presence, and twenty stated that the disease had not appeared this season. The estimates of the damage varied from a slight amount to nearly or entirely the whole crop. Seventeen estimated the loss at less than twenty per cent.; ten reported loss from twenty per cent. to thirty per cent.; three reported loss from thirty per cent. to fifty per cent.; two reported loss from fifty per cent. to seventy-five per cent.; one reported a loss of from seventy-five per cent. to one hundred per cent., and three reported nearly or quite one hundred per cent. loss.

SEED SOAKED IN FUNGICIDES. As stated previously, several methods of treating beans for Anthracnose by soaking the seed in fungicides have been experimented with in field and greenhouse. Laboratory investigations of the disease were begun in January, 1892, and the greenhouse experiments were started soon afterwards. With the seed used and under the conditions of soil, heat

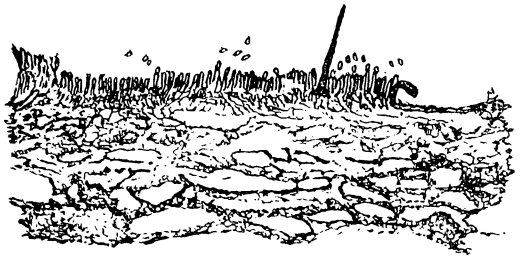


Fig. 3.—Section through an acervulus showing the clustered basidia with spores and the collapsed tissue of the pod underneath. A black seta projects beyond the basidia at the right of which is seen a portion of recurved epidermis of the pod. *Ad nat. del.* $x \frac{100}{1}$ *S. A. B.*

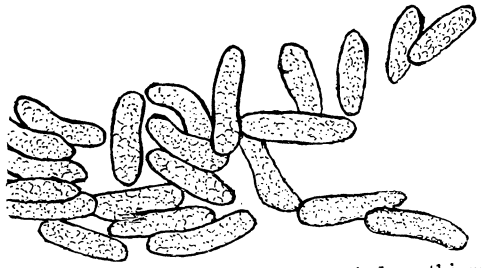


Fig. 4.—Conidia of Colletotrichum Lindemuthianum, $x \frac{600}{1}$ *Ad nat. del. S. A. B.*

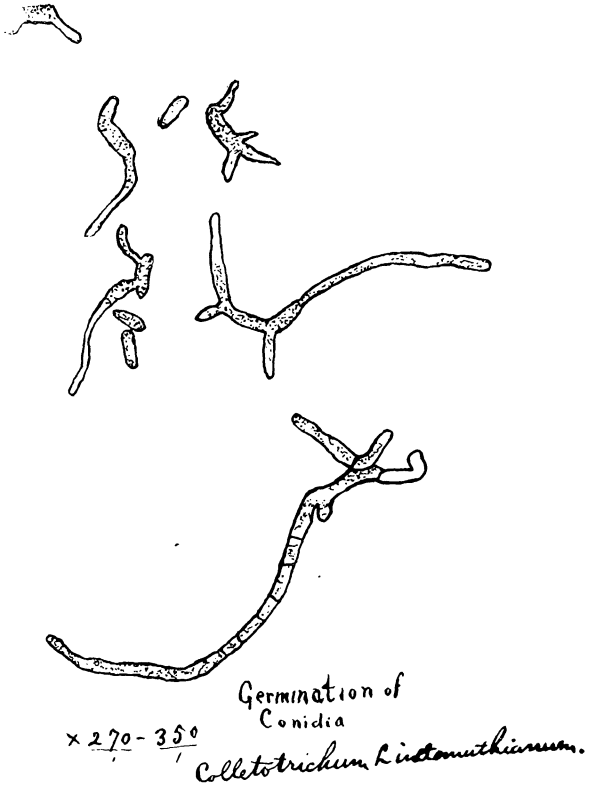


Fig. 5.—Conidia germinated in bean broth. *Ad nat. del. S. A. B.*

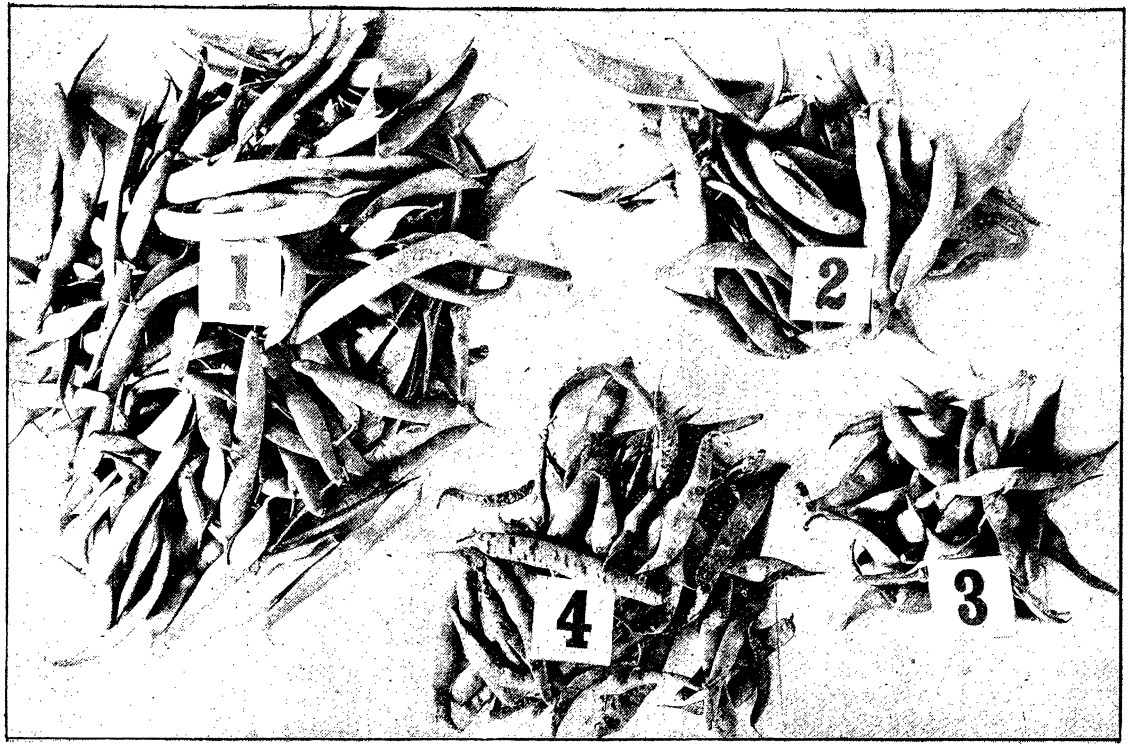


Fig. 6.—Classes *a*, *b*, *c* and *d* from an untreated row.

and moisture found in the greenhouse, the seed could be safely treated by soaking as follows:

1. Water at 140° F. five minutes.
2. Water at 130° F. fifteen minutes.
3. Bordeaux mixture (six pounds sulphate of copper, four pounds lime, twenty-two gallons water) one hour.
4. Ammoniacal solution of copper carbonate (five ounces copper carbonate, three pints ammonia 26°, fifty gallons water) one hour.
5. Potassium sulphide (one ounce sulphide, two gallons water) one hour.

In the last of the greenhouse experiments tried, a bench was prepared with rich soil over a layer of well rotted sod. In it was planted diseased seed treated according to each of the above methods excepting the first one. Three rows were allowed for each treatment and five rows were left untreated. When the young plants appeared there was an abundance of disease on all classes. After a few weeks the remaining plants became well established, and the disease in every case made so little progress that no marked difference could be seen between the plants of the different classes. A comparison of the effects of the various methods of treatment used can therefore best be made from the records of germination and disease during the first weeks of the experiment. Plants removed in thinning the rows are included in this report. It is probable that many of these which were very young but apparently healthy when removed were in reality infected at that time and would finally have dropped into the diseased class as did others like them which were allowed to remain. Of course, when there was any choice the best plants were always allowed to remain. By means of the following table the apparent results of the different treatments may be compared.

Treatment.	Per cent. diseased or that failed to grow.	Per cent. healthy.	Per cent. healthy removed in thinning.
Untreated, five rows.....	60	5	38.3
Bordeaux, three rows.....	58.3	16.6	25
Ammoniacal, three rows.	58.3	8.3	33.3
Hot water, three rows....	50	25	25

It appears that the hot water treatment gave the greatest freedom from disease. When this line of investigation was continued

in field experiments the Bordeaux mixture and ammoniacal solution of copper carbonate were dropped from the list of fungicides used in soaking the seed since, as shown in the above table, they gave less favorable results than did the hot water treatment, and in both cases the disease appeared on over half the plants from which under field conditions it might easily spread until every plant in the field was infected. In field experiments with soaked seed the following methods were used :

Hot water. Seed soaked fifteen minutes in water at 120°F. then for five minutes in water at 130°F.

Copper Sulphate. Seed soaked for one hour in solution of Copper Sulphate. Strength of Solution one ounce to one gallon of water.

Iron sulphate (Copperas). Seed soaked in Iron Sulphate for one hour, using one ounce to one gallon of water.

Mercuric Bichloride, (Corrosive Sublimate). Seed soaked for one hour in solution of Mercuric Bichloride. Strength of solution one-eighth ounce to one gallon of water.

Some of the results obtained from these experiments are compared in the following table :

	I Comparison of stand.	II Comparison of yield.	III Comparison of poor beans.
Hot Water.....	43	84	88
Untreated.....	100	100	100
Copper Sulphate.....	21	28	136
Untreated	100	100	100
Iron Sulphate.....	88	71	132
Untreated.....	100	100	100
Mercuric Bichloride..	28	19	81
Untreated	100	100	100

In column I is given a comparison of the stand of plants secured under each treatment from equal areas, counting the stand from untreated seed in each case as 100.

In column II the total yield of marketable beans is compared in the same way.

In column III a similar comparison is made of the percentage of poor beans in the total yield in each case.

For example, column III shows that for every eighty-eight ounces of poor beans produced under hot water treatment there

were 100 ounces of poor beans produced from an equal yield of untreated plants. The reason why the latter class is credited with the larger total yield in column II is plainly because a much better stand of plants was secured as shown by column I.

It appears that in all these experiments the hot water treatment has given better results than treatment with any other fungicide used in soaking the seed. The important fact to notice is that the untreated seed gives a greater yield of marketable beans than do any plots of the treated seed. This is not because plants from untreated seed were any less diseased but because they gave a better stand of plants. Even when the treatment of the seed by the best fungicides is so severe that the stand is seriously injured there remains enough of the disease to injure the crop under field conditions. At the time of harvesting the crop in the above noted experiments not a sound plant or even a sound pod was found in the whole lot. These results certainly give little encouragement for hope that treatment of seed with fungicide will yield sufficiently good results to justify recommending its adoption. It should be noted, however, that with plants grown indoors for twenty-four days Dr. Halsted found* beneficial results from soaking seed for two hours in ammoniacal solution of copper carbonate five times the strength used in the greenhouse experiment reported above. He reports that one-fifth of the plants from treated seed were affected by the disease and these but slightly, while nearly one-half the plants from untreated seed were badly affected. Sixty per cent. of the seeds germinated in each lot.

SELECTION OF HEALTHY SEED. One experiment was conducted in order to compare plants from healthy seed with plants from diseased seed. The so-called healthy seed really contained some affected beans, as was apparent when they germinated. The sorting of the seed was not done personally and though most of it was healthy, yet a second sorting with great care would have discovered other imperfect specimens. This seed was planted in two equal areas, and the adjacent grounds on one side of each was planted with diseased seed of the same variety obtained from the same source. The soil was uniform in character for both classes and uniform treatment was given to both. The crop was

*Annual Report N. J. Experiment Station, 1891, page 286.

gathered as snap beans and a record of the yield was kept both by weight and by number of pods produced. In order to determine accurately the severity of the disease the pods were classified as follows :

a. Free from any appearance of disease.
b. Slightly diseased.
c. Badly diseased.
d. Very badly diseased.

Figs. 6 and 7 from photographs will assist in giving an idea of this classification. The pods shown in Fig. 6 are from an untreated row. Those shown in Fig. 7 were picked at the same time from a corresponding row treated with Bordeaux mixture, and well illustrate the good effects of spraying. In each case the plants came from diseased seed. Group No. 1 in each figure shows the amount free from disease ; No. 2 shows those slightly diseased ; No. 3 shows those badly diseased, and No. 4 shows those very badly diseased.

Five pickings were made, the last one September 27. The records of the season's yield were then combined in one table. In order that this report might not be needlessly cumbered with tables, a somewhat arbitrary method was employed to find one numerical expression for the amount of injury from Anthracnose in each case. To do this it was necessary to estimate the per cent. of injury represented by each one of the three classes, "*b*," "*c*" and "*d*." This was done, and, on consultation with the two persons who assisted in assorting, five per cent. was adopted to express the amount of damage in class "*b*," forty per cent. for class "*c*," and ninety per cent. for class "*d*." If the percentage of injury thus found is deducted from the total yield of each of these three classes and they are then combined with class "*a*," the result will state the yield for each experiment less the percentage of total damage to the pods from Anthracnose. It is a difficult matter to express either in words or in figures the degree of damage to the crop from the disease. The above method was adopted because it includes in the record those pods which were too badly diseased to ripen seed. It will be seen at once, since there may be many of these in a diseased field, that a record of the yield of ripened beans could not give an accurate expression of the amount of disease.

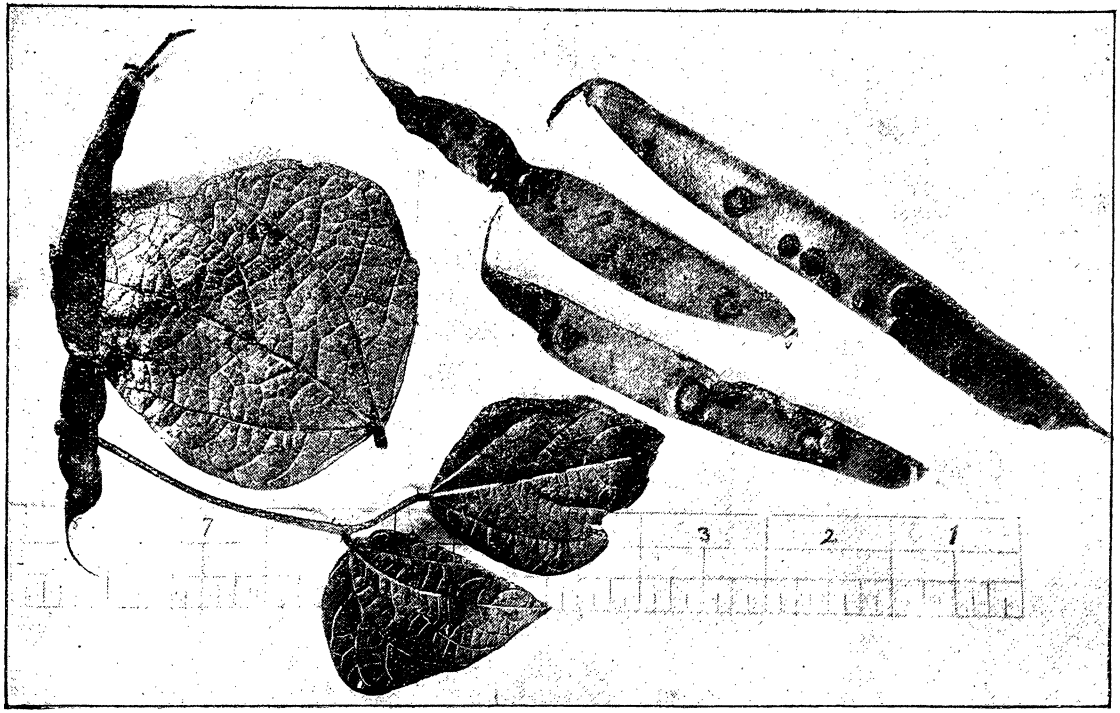


Fig. 2.—Anthracnose on pods and leaves. The black veins, mid-rib and spots in the leaf (parenchyma) show the work of the disease.

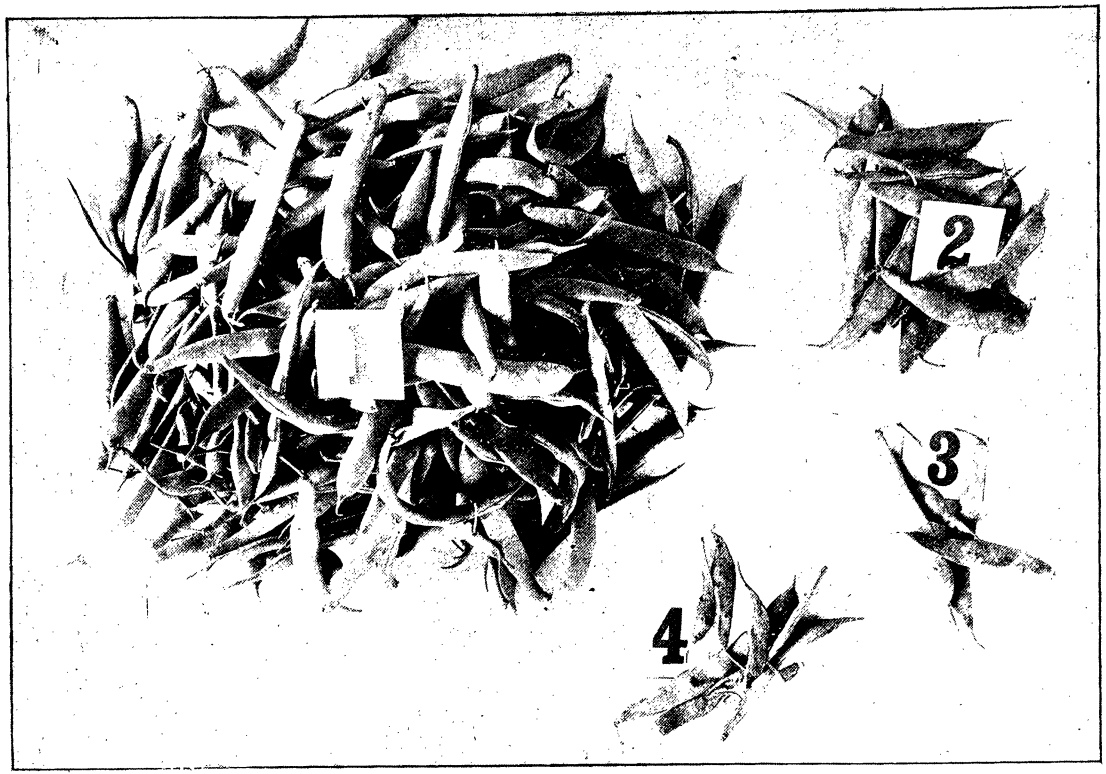


Fig. 7.—Classes *a*, *b*, *c* and *d* from Bordeaux treated row.

In the following table, column I gives the comparative stand of plants from equal areas planted alike, counting the stand from healthy seed as 100. Column II gives the comparative yield by number of pods, counting that from healthy seed as 100. The yield here given is the total yield less the percentage of injury from Anthracnose. Column III in a similar way compares the yield by weight. Column IV gives the comparative amount of damage done to foliage at the close of the season, September 27, 1892, counting the damage to plants from healthy seed as 100. The damage to foliage at this date was partly due to bacterial blight, and it was impossible to make separate estimates of the effects of each disease. The estimate was very carefully made with the assistance of Mr. D. G. Fairchild.

	I Stand of plants.	II Yield by number of pods.	III Yield by weight of pods.	IV Comparative damage to foliage.
Healthy seed...	100	100	100	100
Diseased seed ..	84	91	83	108

It is instructive to compare with the above the following table, showing in a similar way the comparative condition of the plants earlier in the season, at the time of the first picking.

	I Stand of plants.	II Yield by number of pods.	III Yield by weight of pods.	IV Comparative damage to foliage.
Healthy seed...	100	100	100	100
Diseased seed ..	84	62	58	175

This shows plainly that the effect of the disease on plants from healthy seed became more and more marked as the season advanced. At the time of the first picking, they were ahead of the plants from diseased seed by thirty-eight points on yield of pods, forty points on yield by weight, and seventy-five points on condition of foliage ; but for the entire season the difference was but nine points, seventeen points and eight points, respectively. The few diseased plants discovered among this lot as the beans were coming up, were purposely left, and they have furnished an excellent object lesson on the importance of eradicating the disease in the beginning of the season. From these plants and from the plants in adjoining rows grown from diseased seed, the Anthrac-

nose undoubtedly spread to the healthy plants and in a marked degree reduced their yield.

TREATMENT BY SPRAYING. This part of the subject has already been quite fully discussed, but only the Bordeaux formula there recommended has been given. The Cupric Borate formula used was as follows: Dissolve two pounds of copper sulphate in water, and separately dissolve in water two and two-tenths pounds of powdered borax; mix and dilute the whole to thirty gallons; finally add soap as for the Bordeaux mixture.

The formula used for Cupric Polysulphide was as follows: Dissolve in water two pounds copper sulphate and separately dissolve in water two pounds potassium sulphide; mix the two and dilute to thirty gallons; add soap as before.

It will be noticed that these fungicides, as suggested by Mr. Fairchild, contain equal amounts of copper per gallon, and therefore are strictly comparable as to the efficiency of equal amounts of copper in these particular forms. It was noticed after the first application that the Cupric Polysulphide had injured the foliage somewhat and that even greater injury resulted from the use of Cupric Borate. Therefore in subsequent treatment all the formulas were reduced to thirty-seven and one-half gallons of water, instead of thirty gallons. The results do not indicate that it is advisable to use either the Cupric Polysulphide or the Cupric Borate mixture as a remedy for Bean Anthracnose.

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1. SACCARCO AND MAGNUS. Glœosporium Lindemuthianum. n. s. Michelia I, p. 129, 1878. The fungus was first observed by Lindemuth at Popplesdorf in 1875 and is here named in honor of its discoverer.

2. SACCARDO, P. A. Glœosporium Lindemuthianum, Sacc. Fungi Italici, plate 1032, with the above name and the following reference: "Padova, Mich. I, 129, in leguminibus Phaseolus vulgaris. Tunio 1875."

3. ————————. Glœosporium Lindemuthianum, Sacc. and Magnus, Sylloge Fungorum, Vol. III, p. 717, No. 89.

4. FRANK, B. Ueber einige neue und weniger bekannte Pflanzenkrankheiten. Deutschen Botanischen Gesellschaft, Be-

richte der, Band I, 1883, pp. 31-34. *Glœosporium Lindemuthianum*, Sacc. and Magn. States that the disease first became serious in 1882 when the investigations here reported were undertaken. The fungus attacks the half grown pods and continues until they reach normal size. Describes the appearance of the disease on the pod and germination of conidia on the surface of the pod and on glass. Mentions the formation of a secondary spore with dark violet membrane on the surface of the pod from which a germ tube enters the epidermal cell by piercing through the cell wall. After gaining entrance to an epidermal cell in this way the mycelium rapidly develops and spreads to the surrounding tissue. Describes inoculation experiments which were successful only on the pods. In one instance the fungus fruited within five days after inoculation.

5. TRELEASE, WM. The Wax Bean Fungus. The Country Gentleman, Vol. L, p. 800, Albany, N. Y., 1885. One and three-fourths columns with illustration of conidia and diseased pod. A popular discussion of the general appearance and microscopic characters of the disease. States that it attacks stems, leaves and pods of the common bean, *Phaseolus vulgaris*,, L., especially the white wax variety. Mentions the susceptibility of some varieties and discusses the probable causes, stating that "The susceptibility of the wax beans to the attacks of this fungus is not improbably connected with the very delicacy of its tissues—which are still healthy tissues—* * * for which we prize it."

6. SORAUR, P. Pflanzenkrankheiten, Vol. II, pp. 422-423, second edition, 1886. Gives botanical characters of *Glœosporium* genus and states in substance the description of *Glœosporium Lindemuthianum* as given by Frank.

7. PENZIG, Dr. O. "Studi Botanici Sugli Agrumi e Sulle Piante affini, Ann. d. Agria., 1887, Pl. XXXVIII, Figs. 3 and 4, p. 384, has figured and described *Colletotrichum glœosporioides*, and so far as can be judged from the illustrations the fungus has every generic characteristic of that upon the bean. In his Funghi Agrumicoli, 1882, p. 66, Fig. 90, Penzig described the same fungus as *Vermicularia glœosporioides*." The above reference is quoted from the 1887 report U. S. Department of Agriculture, p. 864.

8. SCRIBNER, F. L. Anthracnose of the Bean. *Glœosporium Lindemuthianum*, Sacc. and Magn., Report of Section of Vegetable Pathology in U. S. Department of Agriculture Report 1887, pp. 361–364, with colored plate of diseased pods, acervulus, conidia and sections of diseased spots on the pod. Under *General Observations* states that this fungus attacks water melon rinds. Gives external characters of the disease on the bean, conditions favoring the disease, botanical characters and suggestions for treatment. Notes the presence of setæ in the acervuli and remarks that if these prove an organic part of the fungus the classification will probably be charged to *Colletotrichum Lindemuthianum*.

9. ———————— Anthracnose of the Bean. *Colletrichum Lindemuthianum*, Orchard and Garden, Vol. xi, pp. 193–194, Little Silver, New Jersey, Oct., 1889. Refers to the article in the 1887 Report of the U. S. Department of Agriculture, just quoted, and adds observations on the injury caused by the disease. States that field beans are subject to its attacks and no varieties of "string" beans are exempt, not even those with green pods. Notes again the presence of setæ in the acervuli "the presence of which separates our fungus from the genus *Glœosporium* under which it has heretofore been classed and places it in the genus *Colletotrichum*, the name here adopted." Gives suggestions as to treatment. The article is illustrated with two ffgures, one showing a diseased pod, the other the microscopic appearance of the fruiting fungus.

10. BRIOSI AND CAVARA. Colletotrichum Lindemuthianum (Sacc. and Magn.) Briosi et Cavara. I Funghi parasiti della pianti coltivate ed utile, No. 50, Pavia, Italy, summer of 1889. They refer to Scribner (see No. 8) stating that he first noticed the setæ but as they find these setæ constantly present they decide to change the generic name to *Colletotrichum*.

11. GALLOWAY, B. T. Anthracnose of the Bean. Bulletin No. 8 Botanical Division U. S. Department of Agriculture 1889, p. 65. Replies to letter of inquiry from New Orleans, La., regarding this disease and states the cause suggesting remedies. On page 64 of the same bulletin this fungus is noted as destructive to melon leaves in North Carolina where it is called "melon rust."

12. KIRCHNER OSKAR. Die Krankheiten und Beschädigungen unserer Landw. Kulturpflanzen, p. 77. Stuttgart 1890. Gives a brief statement of the appearance of *Glœosporium Lindemuthianum*, Sacc. and Magnus, on bean pods and young seeds. Recommends if possible planting in dry airy situations.

13. HALSTED, B. D. Fungi Injurious to Garden Crops. Ohio State Hort. Soc. Report of meeting December 1890. Mentions *Colletotrichum Lindemuthianum* as causing "bean spot" and states that it probably also causes "melon rot."

14. ———————. Anthracnose in Bean Seeds. Garden and Forest, Vol. v, p. 18, 1892. States that "It is certain that *Colletotrichum Lindemuthianum* can exist from one season to to another in the mature beans and when these diseased seeds are planted the best possible condition is given for perpetuating the disease." It is recommended that before planting the seed be soaked one hour in a solution of three ounces of copper carbonate, one quart of ammonia, and four and a half gallons of water.

15. BEACH, S. A. Anthracnose of Bean, Country Gentleman, Vol. LVII, p. 88, 1892. Notes the development of the disease from blistered beans which though blistered were not noticeably discolored. Suggests treating the seed by soaking as recommended by Dr. Halsted in Garden and Forest of Jan. 13, 1892.

16. Frank and Sorauer. Pflanzenschutz, p. 62, Berlin, 1892, Paul Parry. A short note on treatment of bean anthracnose states that with pole beans copper salts are effective as a remedy if applied early. An excellent figure illustrates the appearance of the disease on affected pods.

Prof. L. H. Pammel, E. G. Lodeman and D. G. Fairchild have kindly assisted the writer in compiling the above references.

BEAN BLIGHT.

In the article on Bean Anthracnose reference was made to a bacterial disease which in some cases is even more destructive to beans than anthracnose. In the kitchen garden at this Station it was very destructive during the past season. It developed into a serious malady about the first of August and did the most damage during the hot weather of that month. A plat of wax beans was

the first to be badly affected and the plants were ruined within a few days after the serious nature of the disease first attracted attention. The foliage became spotted and yellowed in large areas of the leaf surface and soon the leaves withered and fell away. Many of the pods contained soft or watery spots showing the presence of the disease, or they became withered from lack of nourishment after the foliage was destroyed. From these beans the disease spread to an adjacent plot of a different variety and it also was soon completely ruined.

In its early stages this blight forms small pimples which have a watery appearance. These may occur on the pods, blossoms (?) foliage or stems. They may or may not have a dull red border but do not have either the black color or the sunken spots which characterize anthracnose. Microscopic examination in the early stages of the blight failed to reveal the presence of any mycelium but bacteria were always present. In later stages saprophytic fungi gained entrance through the diseased places and hastened the destruction which the bacteria had inaugurated.

The question suggested itself whether the blight might not be an accompaniment of the anthracnose attacking the tissues already parasitized by this fungus. The question was answered in the negative by the fact that in one field blight was found everywhere present on Mexican tree beans while no trace of the anthracnose could be found on any plants of this variety though they were growing adjacent to Red Kidney beans which were attacked by the anthracnose. At the close of the season Mr. J. W. Stepfield of Horseheads, N. Y., in whose field these things were noticed reported that the anthracnose did not appear on the Mexican tree beans at all during the season.

This blight affects the foliage and pods as before stated and also affects the beans within the pods. Some of the pods fail to ripen while others which mature, produce beans that are discolored by the disease or wrinkled or disfigured with rough spots. It is possible that the blight may be communicated to the crop of the following season in the seed, as is probably the case with the blight of lima beans, and therefore all blemished seed should be rejected when planted. Whether this blight on the common beans, *Phaseolus vulgaris*, L. is identical with the one next de-

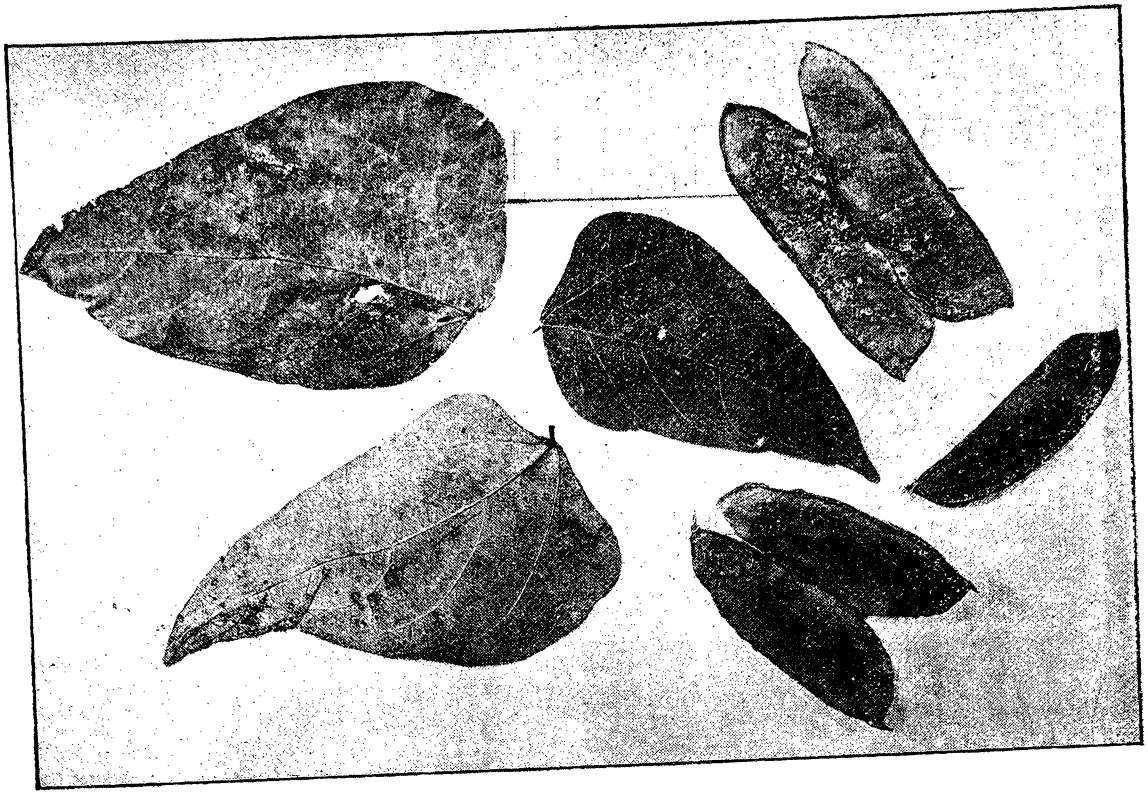

FIG. 8—Bacterial blight on pods and leaves.

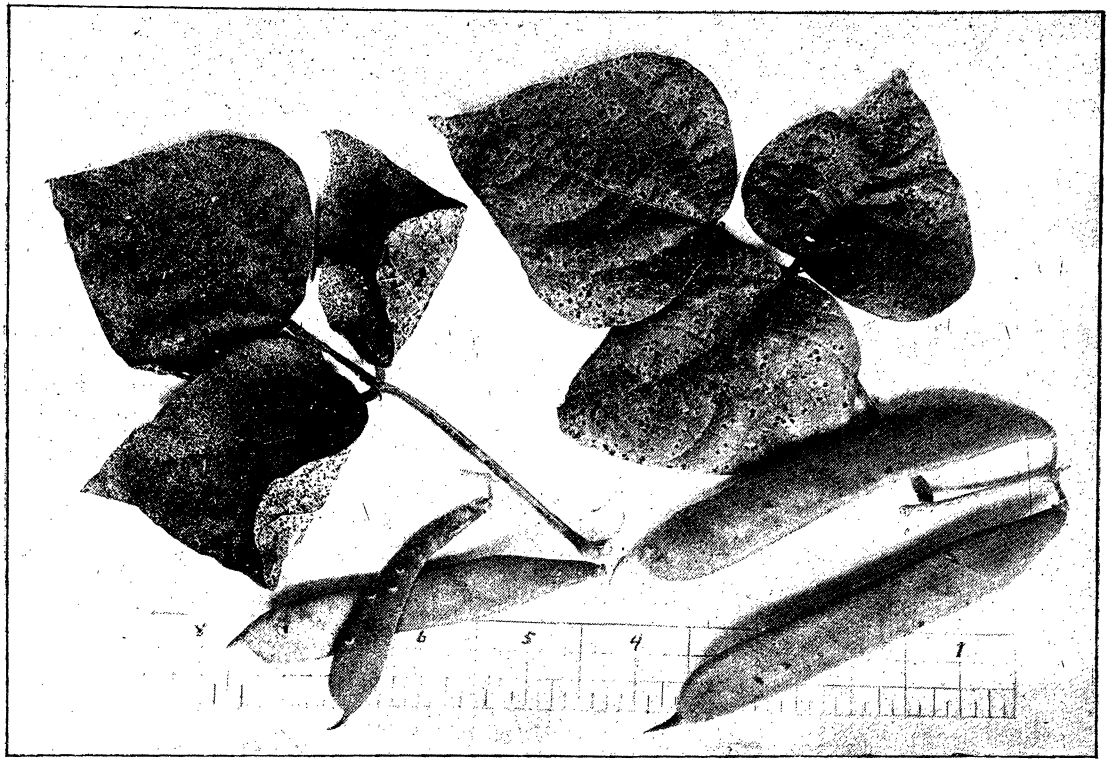

FIG. 9—Bean rust (Uromyces Phaseoli) on pods, stems and leaves.

scribed as attacking Lima beans is a question not yet decided. The subject is under investigation and the results will probably be noted in a subsequent report.

Blight of Lima Beans.

A bacterial disease occurs in Lima beans and forms definite characteristic spots on pods and leaves, especially in its earlier stages. These spots differ in appearance from those formed by the blight on *Phaseolus vulgaris*, but whether the difference in appearance is due to the influence of the different host plants, and the blight in both cases is due to the same germ has not been decided. Probably the two diseases are distinct. Fig. 8, from a photograph, shows the characteristic spots on leaves and pods of Lima beans. So far as noticed, these spots are never black, but often have a reddish purple border inclosing an area of a light red color. On the leaves the spots gradually increase in size and develop a straw colored center of dead tissue. Sometimes the centers of the spots on the pods also become straw colored. In the Station garden this blight did considerable damage, and on Oct. 10 it was almost impossible to find a Lima pod free from the disease.

A study of the blight has been made in the laboratory in the following way. The germ was first isolated by means of plate cultures. It was then transferred to various nutrient media and from the latter cultures inoculations were made on healthy pods kept in moist chambers. These inoculations produced decay at the spots where the virus was introduced, while punctures made at the same time, but not inoculated, showed no signs of decay. The germ grew less readily on pods of wax or kidney beans kept in moist chamber and had but slight effect on the seedlings of *Phaseolus vulgœris* when applied to the unbroken epidermis. The tests thus far made indicate that the blight of Lima beans may be propagated by planting the diseased seed. The only treatment at present recommended is the selection of healthy seed.

Bean Rust.

Uromyces Phaseoli, (Pers.) Winter.

Fig. 9 gives an illustration of the true rust of the common field or garden bean, *Phaseolus vulgaris*, L. as it appears on the leaves.

and pods. It may be found also on the stalks and petioles. So far as is known from our investigations, it is not nearly so destructive to beans as either the anthracnose or the blight and it is so distinct from them that a careful observer will at once recognize the difference. It certainly assumes importance in some localities, for Dr. Halsted includes Bean Rust in the class of "Worst Fungi of Garden Crops."* On certain plots of beans grown at this Station during the past season the rust was very abundant, but the attack came quite late in the season and the foliage suffered but slightly as compared with the injury to other plots from blight and anthracnose. The disease was seldom found on the pods and did no perceptible injury to them. Specimens of the fungus were submitted to Prof. George F. Atkinson, who reported that "The specimens of *Uromyces* on *Phaseolus vulgaris*, L. I find on comparison to be the *Uromyces appendiculatus*, (Pers.) Lev. It agrees with specimens in Rabenhorst's Fungi Europaei marked No. 1292, *U. appendiculatus*, (Pers.) Lev., and No. 2168 *U. Phaseolarum*,(Wall.) DBy, a synonymous species. Probably the question as to what the name is is one of synonymy. *Uromyces Phaseoli*, (Pers.) Winter† is probably the name that should be used.

On the foliage the Bean Rust first forms little brown spots nearly circular in outline about as large as pin heads. These break out all over the leaf on either surface, and the spores produced in them are soon discharged as a rusty brown powder. After an indefinite time these spots change in color from brown to black and produce spores of larger size and different shape and texture. It frequently happens that one leaflet is sprinkled with the brown spots while its companion on the same leaf stalk is covered with black spots or both kinds of spots may be found on one leaflet. This is not strange since the different colored spots represent different stages of the same disease. The dust which they discharge is composed of spores which have the same function as do the seeds of higher forms of plant life, namely, the propagation of the species.

The fungus grows inside of the leaf for sometime before the rust spots break out and the need of treating the disease is not re-

*Proceedings New Jersey Hort. Society, winter meeting 1889-90.

†Die Pilze, bd. I., p. 157, Winter's Rabenhorst's Kryptogamen Flora.

alized till the rust spots appear. It is then impossible to destroy the fungus without killing the foliage with it. We are not aware that any experiments have been tried for the purpose of controlling this disease and therefore no recommendations as to treatment of Bean Rust are made at present. It is not known to live over winter in the seed. Probably it winters in the rusted leaves as is the case with Wheat Rust which resembles Bean Rust in its botanical characters.

ERRATA.

Page 313, line 10, should read p. 320 not 19.
" 314, " 7, " " p. 323, " 23.
" 314, " 8 from bottom, should read p. 325, not 26.
Page 319, line 20, should read "right," not "left."