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**ROOT-ROT OF TOBACCO**

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*Discovery of the trouble in Connecticut.* During the past season a serious root disease of tobacco has been prevalent in certain seed beds and fields in this state. While probably not an entirely new trouble, it certainly has not heretofore attracted any special attention among tobacco growers. Neither has the fungus [*Thielavia basicola* (B. & Br.) Zopf] causing it been previously reported on tobacco by the botanists of this station, though Thaxter in 1891 found it causing serious injury to violets. Mr. Shamel, of the United States Department of Agriculture, who is coöperating with this station in a study of the improvement of tobacco by selection and breeding, was the first to report it on this plant in the state. In an interview with Mr. Shamel printed in the Hartford Daily *Courant* of

May 28 of the present year, attention was called to the serious injury caused by the root-rot in the tobacco beds of the Connecticut valley. It was also stated in this article, apparently from personal observations, that this disease had proved a very serious pest in Cuba, and had spread to an alarming extent all over the tobacco-growing districts of America. Mr. Shamel strongly recommended sprinkling the seedlings, in seed beds showing the trouble, with formalin. In view of this serious report, which was partially copied in a number of papers over the state, and because of its especial interest in the tobacco industry, this station, through its director and botanist, made a careful study of the diseased seed beds and the fields during the remainder of the season. There is given here a brief preliminary report of this investigation.

*History elsewhere.* The fungus responsible for this trouble was first described from England by Berkeley and Broome in 1850. They reported it as a probable parasite on the base of the stems of peas and another plant. Zopf, of Germany, in 1876, however, was the first to give a complete account of the different stages of the fungus. He found it injuring the roots of a species of *Senecio*, and some years later also on the roots of a number of leguminous plants. Thaxter was the first to report the fungus from America, having found it, as previously stated, on the roots of violets in this state. Peglion was apparently the first to find the fungus injuring tobacco. In 1897 he made a report of injury to the roots of tobacco in the fields of Italy. He thought that the water-clogged condition of the soil was in part responsible for the serious injury done by the fungus. Selby, of the Ohio Experiment Station, was the first to find the fungus on tobacco in the United States, having seen diseased specimens from seed beds as early as 1899. In a bulletin published in 1904, while noting that the fungus caused evident injury in the seed beds, he states that "the field development of the trouble remains open for study with us." So far as the writers have learned, this trouble on tobacco has been definitely reported in literature only from Italy, Ohio and this state, if we omit the general statement of Mr. Shamel noted above.

### IN THE SEED BEDS.

*Difference between dampening-off and root-rot.* For years the tobacco seed beds of Connecticut have been injured more or less by dampening-off fungi. These dampening-off troubles, however, are quite distinct from the root-rot disease. With the former, the stems of the young plants are attacked above ground by certain fungi which, when soil and air are very moist, may develop on the surface of the beds and on the base of the plants as delicate, whitish, cobweb-like growths. These filaments of the fungus penetrate into the tissues of the stem and induce a soft rot of the tissues which causes the plants to collapse and a further rot of the leaves takes place, especially if in contact with the ground. Thus vacant spots appear in the beds where all the plants have been rotted out; or, when the trouble is not so bad the stand is thinned by the death of a few individuals. Frequently a plant may be attacked, but, through rapid growth or moisture conditions unfavorable for the development of the fungus, escape injury further than a cankered area on the stem. These dampening-off troubles are augmented by very damp and cloudy spring weather, and not infrequently are started by lack of skill or care in watering or ventilating the beds. As the fungi are capable of living in the vegetable mold of the soil, they become established in the beds and cause more or less injury each year.

*Characteristics of root-rot.* The root-rot fungus, on the other hand, develops almost entirely underground, attacking the roots and underground part of the stem. The tap root, which is prominent in the young plants, is often rotted off close to the stem or there may be a general rotting of the tap and secondary roots, as shown in figure 2. Not infrequently severely injured plants form new secondary roots further up on the stem and under favorable conditions partly or entirely outgrow the trouble. Sometimes the roots are only slightly injured, having the secondary roots rotted off near their ends or there are scattered diseased spots that may be finally outgrown, as the fungus does not develop so readily on the larger and harder roots. All of this injury, except rarely a cankered spot on the base of the stem, is hidden from view until the plants are pulled up. When this is done one is often surprised to

find how easily the plants separate from the soil, but an examination shows that there were few or no roots to hold the plants to it.

The grower usually first notices the trouble by the plants failing to make normal growth or coming entirely to a standstill. The leaves may show to his critical eye an unhealthy dark green color which he often describes as black. In time there is a very uneven stand of the plants in the bed due to some plants being more injured than others. Eventually there may be a sickly yellowing of the older leaves. While some of the plants are killed when quite young and others may be carried off later, still it is very remarkable how many of the plants continue to live even when most of their roots have been rotted off. On a bright day this lack of root system becomes evident through the premature wilting of the plants. Later in the season the beds may show considerable improvement, since the plants have had time to develop new roots and the warmer drier weather is more favorable for their outgrowing the disease.

*Extent of the trouble.* In order to determine how general the trouble was in the seed beds of the state, the writers, by visits, personal inquiry and correspondence, attempted to locate as many of the infested beds as possible. Such beds were seen at Simsbury, Granby, Tariffville, Poquonock, Hockanum and Portland. In all, however, the disease was definitely located in the beds of less than a dozen growers. Often only one of the beds of the grower was seriously injured. No doubt this does not show the complete distribution of the trouble, as some growers are reticent about giving information concerning such diseases. Others may have suffered but slightly from the trouble and so it would easily escape their notice, still others may have suffered in ignorance of its real nature, as some growers at first were inclined to lay the trouble to fertilizer burn. All of these infested beds were in the Connecticut valley, the chief tobacco region of the state. Although similar effort was made to find the trouble in the smaller tobacco region of the Housatonic valley, not a single case was found or even heard of in this region.

*Loss caused.* The disease at its worst practically ruined the beds, as none of the growers would risk planting from such

beds. This meant the loss of time, etc., in taking care of the bed, often the purchase elsewhere of healthy plants and frequently a delay in setting out the fields. One grower estimated that this loss to him was equal to one hundred dollars. In other cases growers, who set from beds that did not show the trouble badly, became scared afterwards because the plants did not start promptly, and they plowed these up and reset with plants from uninfected beds. This was probably wise, at least it was taking no risk, though we know of one grower who set from beds showing the trouble rather prominently and yet raised a very good crop of tobacco.

#### IN THE FIELDS.

*Effect on the plants.* Some badly diseased plants set out by the writers were a long time in getting started but later made a satisfactory growth, if this first backset was taken into consideration. These plants were set in uninfected soil, and when the roots were examined at the end of the season they showed very little of the fungus, and in some cases were entirely free from it. On the other hand, certain plants free from the disease that were set in a bed containing the disease became badly infected and did poorly the whole season. This may possibly explain why some growers who were not troubled at all by the disease in their beds suffered severely from the trouble in their fields—such fields being already infected with the fungus. Beside the backset early in the season, which many plants entirely or largely outgrew, there were other cases where the plants made no satisfactory growth the whole season. Examination of the roots showed that the fungus had continued its injurious action here during the season. Such plants usually did not have the normal main and fibrous root system shown in the healthy plant in figure 3a; but the main roots were more or less rotted off or easily broken when pulled up from the ground, and the development of the fibrous roots and rootlets was very deficient (see figure 3b) or abnormally clustered at the crown. The fungus evidently can work on the young rootlets and the small fibrous roots much easier than on the larger and more woody secondary roots. While it sometimes rotted off the larger roots, it more frequently showed as an encircling banded

blackish growth that was apparently doing comparatively little injury. These blackish growths (fig. 4b), in the examination of the washed roots, gave a very good idea of the abundance of the fungus and its probable injury to the plant. So far as was learned, the fungus did not attack any part of the plant above ground, though occasionally plants with black sunken areas were found where the trouble may have had its start from a root-rot injury.

*Extent of the trouble.* In order to determine how general the fungus was in the fields, the writers made a careful examination of forty-six different fields scattered over the state. These were examined chiefly after the tobacco had been cut in the fall. The roots of at least ten plants in different parts of each field were pulled up and washed and then examined for the characteristic black spots of the fungus. These tests were verified later by a microscopic examination. Twenty-eight of these fields were in seven different towns in the tobacco region of the Connecticut valley. In all of these fields, except two, the fungus was present, at least to some extent on the roots, thus showing it to be quite general in its distribution in this valley. In two towns in the Housatonic valley eighteen fields were examined, but the fungus was found only in eight of these.

*Damage done.* In none of the fields in the Housatonic valley was the fungus found in any abundance, and in most of the eight cases only a trace of it was seen on a few of the roots. Neither was there complaint by the growers of any trouble that could at all be attributed to this fungus. So it can be pretty safely stated that in this valley there was no injury this season from the root-rot. In at least eleven of the twenty-eight fields in the Connecticut valley the fungus was found abundant enough on the plants examined to have caused appreciable injury. In all of these cases conversation with the owners showed that the field as a whole or in spots had not done as well as it should have done. In some cases it was merely a small spot or portion of the field that did not give a normal growth, and an examination of the roots from these places always showed more serious injury by the fungus than in the rest of the field. Serious damage to the fields as a

whole, however, was confined chiefly to the region of Suffield, and here the root-rot was most abundant. In this town a number of the fields of some of the best tobacco growers did unusually poorly in a year when the crop in general was unusually good. In these fields the tobacco at harvest time was smaller than it should have been and on certain areas made no satisfactory growth through the season and so was practically worthless. The tobacco from these poorest spots often failed to cure down properly in the barns, some leaves still remaining green late in October, when the main bulk of the crop in the same barn was ready to come down. As some of the most seriously injured fields were of considerable size, this short crop, and the inferior quality of at least a part of it, meant a serious loss to the growers.

The questions arise, is this trouble likely to occur as seriously in the worst fields another year, and will it grow more injurious in time in the fields where it is at present doing little or no damage? It is not possible to answer these questions definitely, because there are other factors than the mere presence of the fungus in the field that have an influence in determining the injury done, and at present we do not know the exact value of these factors. They are briefly discussed in the following paragraphs.

*Secondary factors possibly determining the injury in the fields.* Some of the growers, especially with the seed bed trouble, were inclined at first to look upon the injury as a fertilizer burn. There seems to be little ground for this belief as regards the seed beds. Whether or not the presence of more or less of certain of the fertilizers used would stimulate or retard the growth of the fungus is another question not so easily answered. It is not definitely known whether an acid, alkaline or a neutral soil is best adapted to the growth of the fungus, which we know can grow in the soil itself apart from the tobacco root, but it is reasonable to suppose that this factor may have its influence. Neither can we state positively whether or not certain methods of field fertilization (showing in an excess or lack of certain fertilizer constituents this season) had an injurious action on the development of the tobacco aside from, and possibly in the worst fields greater than, the injury

that was evidently caused by the root-rot fungus. One of the growers whose fields suffered severely was inclined to lay it to the excessive use year after year of potash fertilizers, which gradually accumulated in the soil, and especially to the use of the carbonate of potash. Possibly the use of infected manure may have had a bearing, as this would be favorable for the development of the fungus. No special evidence, however, was obtained along this last line unless it was in the case of one of the seed beds.

A very prominent factor, undoubtedly, is moisture. One grower stated that the worst infected fields in Suffield were those that had been under tents a couple of years previously. If this was generally true, it is possible that the more moist condition of the soil when under the tents gave the fungus a better chance to develop and infect those fields later. A very moist soil seems to be most favorable for the development of the fungus, as the lower or damper spots in the fields usually showed the most trouble. The nature of the sub-soil as regards drainage also may have had its bearing, especially early in the summer. The character of the past season no doubt was also an important factor. The cold wet weather of early spring helped along the trouble in the seed beds, particularly when they were not properly ventilated. The rainfall\* in June and July was considerably above the average, which was no doubt favorable for the growth of the fungus in the fields and may have had its bearing on the fertilizer question.

Taking all of these factors into consideration, and the fact that the trouble appeared so suddenly and prominently this year when no doubt the fungus must have been present in the soil, at least inconspicuously, for some time (as it now is in some parts of the Housatonic valley, with no injury to the crop), the writers are inclined to believe that it is not certain that the trouble will appear next year and thereafter with increasing severity. However, it is very desirable for the growers to be well informed regarding the nature of the trouble and to do what is feasible in the way of preventive measures.

\*The rainfall at New Haven for June was over 5 inches, giving an excess of considerably over 2 inches when compared with the average for thirty-four years. The excess for July was .68 of an inch.

## PREVENTIVE MEASURES.

*Use of infected seed beds.* The common experience of the growers whose seed beds were worst infected was that the trouble had appeared in them last year to a limited extent. This seems to indicate that the fungus, like most other soil fungi, after it has become established in a bed will do more or less injury each year—though no doubt the season and the attention given the bed will influence its development. It seems desirable, therefore, not to use the infected seed beds again for some time when new ones can be conveniently made. Most growers, however, are reluctant to give up their old beds either because of their handy location, the fine condition of the soil or for other reasons. In these cases it will be desirable to use some form of sterilization to eradicate the fungus.

*Sterilization of beds.* Sterilization of the beds is helpful, not only in preventing or lessening injury by the root-rot and dampening-off fungi, but it also destroys more or less of the weed seeds and insects. Three methods have been used with more or less success on tobacco and other seed beds: 1st, Burning dry tobacco stalks or other fuel on the beds under a metal cover, which throws the heat down into the soil, has been tried somewhat in this state for destroying weed seeds. It is said to be quite helpful in this respect, and it will probably also kill the soil fungi, near the surface of the ground at least. Too hot a fire, however, may burn out the humus of the soil or make plant food less soluble and so do as much harm as good. 2d, Sterilization by steam has been profitably employed against soil fungi and nematodes in greenhouses and hot beds for some time, and is now used in a few cases in this state to kill the weeds in tobacco beds. There is no reason why it should not be as successful in killing the root-rot fungus as the other soil fungi. There is on the market a steam rake whose points when forced into a bed carry the steam into the soil from any attached steam boiler. The chief objection to this method of sterilization is the cost of the apparatus and the trouble and time taken in heating the beds. 3d, Treating the soil with formalin is another method that is coming into use for combating soil fungi. Preliminary tests with this method were made this past summer against the root-rot fungus in the greenhouse and

also in part of one of the badly infected beds, see figure 1. The results from these tests were so encouraging that we give the following tentative directions for its use:

It is perhaps better to treat the beds in the fall so that they may have a chance to dry out after the thorough soaking they receive. If treated in the spring they should be aired for a week before planting in order to allow the fumes of the formalin to escape and the soil to dry out as much as it will. Whether in fall or spring, the bed should be treated after the tillage is mostly done, for, if cultivated deeply after the treatment, untreated soil containing the fungus may be brought up from below. Commercial fertilizers may be used either before or after the bed is treated, but manure, if used, should be put on before so that it may be sterilized. Use only the strongest formalin, guaranteed 40 per cent. This can be bought in carboys holding about 100 pounds for 10 cents per pound, or a better article in pint bottles at about 40 cents. It is not necessary, however, to get the chemically pure article, but it is necessary to keep the bottles tightly stoppered to avoid loss of strength through evaporation. One pint of this formalin should be added to each twelve and a half gallons of water used, or at the rate of one to one hundred by volume. This should be applied immediately to the bed with a sprinkling can so as to evenly and thoroughly wet the soil, using two-thirds to one gallon to each square foot of surface. It may take some time for the soil to soak in the latter quantity, but if applied in partial amount it will soak in while the rest of the bed is being treated. The ground should be covered with the sash or canvas for a couple of days after treatment to help keep in the fumes.

*Sprinkling seedlings with formalin.* According to our observations and experiments, a very weak strength of formalin (about 1 to 1500) sprinkled several times on the plants in the infected beds did not give very favorable results. So far as the root-rot is concerned we do not believe this treatment has much value after the appearance of the disease. As regards the dampening-off troubles there was some evidence that this method may have benefited the beds slightly. Possibly if this treatment entirely supplanted the watering throughout the

whole season of the beds, it would prove more serviceable, especially against the dampening-off fungi.

*Treatment of the fields.* It is more difficult to advise as to the best treatment of the fields. Of course it is not desirable to use plants from infected beds. Care in this respect, as stated before, does not necessarily mean that the trouble will be escaped in the fields. One grower has suggested that it might be well to use formalin in the water (1 to 1200) when the plants are set out. While it is not likely that this would prove of any great service, it might be worth trial on a small scale, to determine its value. Some form of rotation may be found necessary if the fungus persists in injuring each succeeding crop. One field was seen the past summer, part of which had been in corn the two previous years, and this part, according to the owner, did better than the remainder of the field; an examination of the roots also showed less of the rot there. Where one has reason to suspect that his soil is acid, it might be well to lime part of the field to see if this will prove helpful to the crop. On the other hand, if a grower has been using large amounts of potash (and the growers who used the most were among those whose fields suffered most) it might be well to cut down the amount used on part of his field and carefully compare this part with the remainder of the field during the season in order to get data for determining the character of his fertilization another year.

*Examination of specimens.* During the coming season any grower who suspects he has this trouble in his seed beds or fields is at liberty to send specimens of the plants or the roots to the Experiment Station, at New Haven, for examination. In cases of severe injury or especial interest, inspection of the seed beds or the fields will be made if desired.

a. Treated.

b. Untreated.

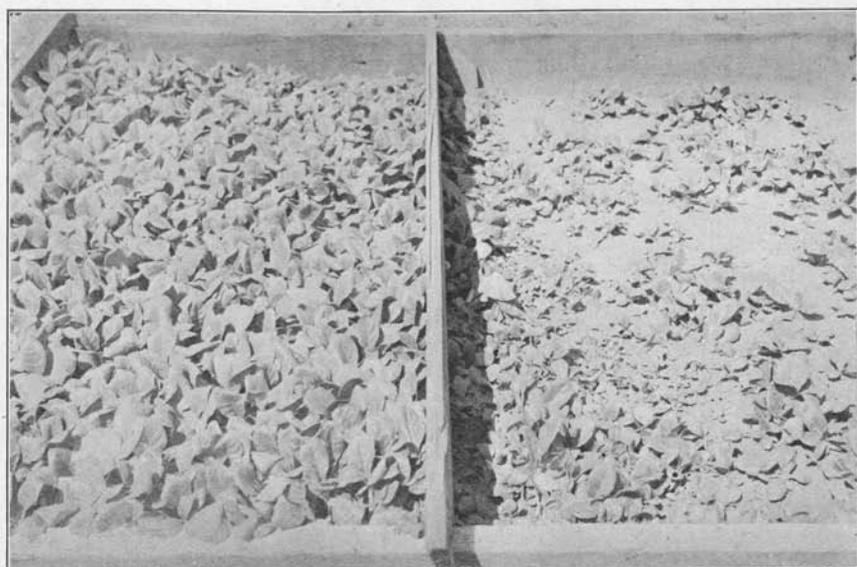


Fig. 1. Apparent effect of soil treatment with formalin.

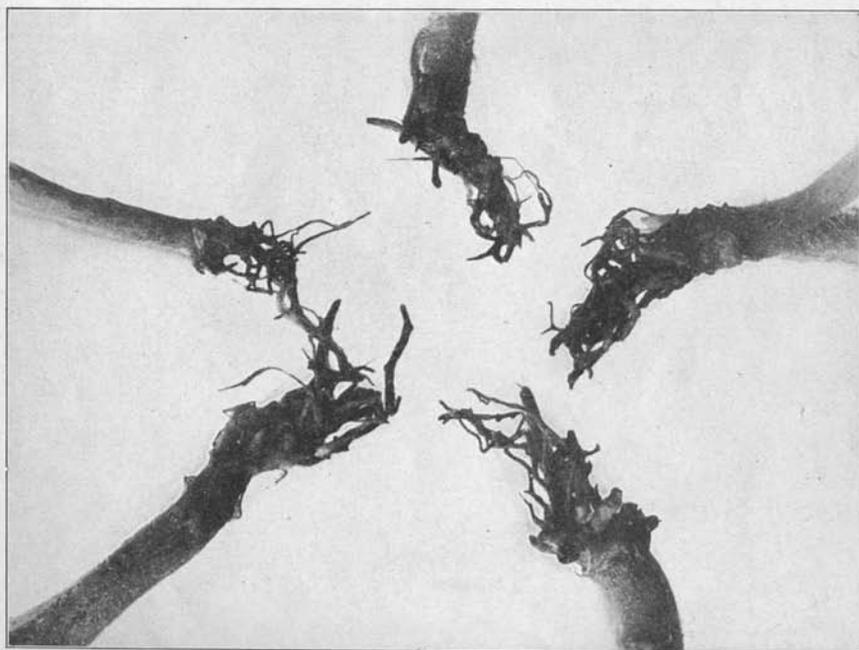


Fig. 2. Effect of rot on roots of seedlings.

a. Healthy.

b. Diseased.

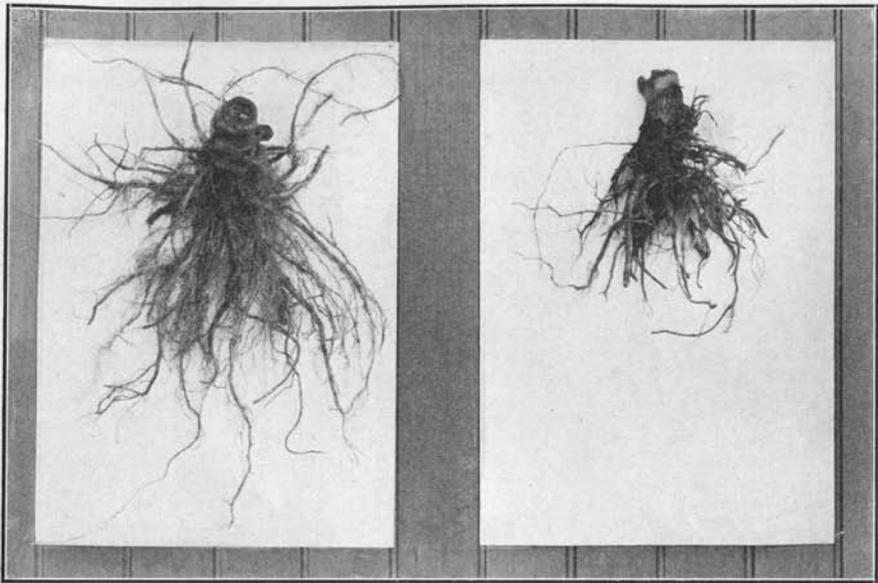


Fig. 3. Effect of rot on roots of mature field plants.

a. Healthy.

b. Diseased.



Fig. 4. Appearance of the fungus on the large roots.