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ROOT ROT OF COTTON, OR "COTTON BLIGHT."

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Root Rot of Cotton, or "Cotton Blight."

In presenting this preliminary report on The Root-Rot of Cotton, or, as it is commonly called, "Cotton Blight," I am fully aware of its uncompleteness, but a communication at this time will call out many suggestions from practical farmers, which may lead to good results in trying to treat the disease. Farmers, as a rule, have been somewhat skeptical when I stated what seemed to me to be the most probable cause of the disease. I have endeavored to bring together the scattered views of those who have given the subject thought, to facilitate work on the subject hereafter. The work cannot be said to be finished till the best and most conclusive evidence has been obtained. I am now at work to determine some of these points. This is necessarily difficult, as we are dealing with a disease that does its mischief in the soil, and unless care is taken wrong conclusions may be formed. Although the destructive work of the disease must annually destroy many hundred thousand dollars worth of cotton, yet scarcely anything has been written on the disease, excepting a few articles inagricultural papers, [1] and some short notices in Government publications. [2]

As it is generally supposed that the character of the soil has much to do with the dying of cotton, it will be well to consider briefly the agricultural features of the State, and see if any relation can be found to exist between the soil and the distribution of the disease.

For classification of the soils of Texas I have followed Dr. H. H. Loughridge's excellent report on the cotton production of Texas.[3]

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1. Colman's Rural World, May 1, and June, 1878; Texas Farm and Ranch, August, September and October, 1886; Texas Farmer, September, 1888; Fruit Growers' Journal, October 1, 1888, etc.

2. Tenth Census Report—Cotton Production in the United States, also embracing Agricultural and Physico, geographical descriptions of the several Cotton States and of California, Vols. V. and VI., Pt. I. and II. Fourth Report of the United States Entomological Commission—On the Cotton Worm, together with a chapter on the Boll Worm, Appendix, III.

3. Tenth Census—Special Report, Texas, Vol. V., Pt. I, pp. 13-48.

The agricultural regions of Texas are classified as follows:

1. Timbered upland region of East and Central Texas.
   a. Oak, hickory and pine lands.
   b. Short-leaf pine regions or pineries.
   c. Red hill lands.
   d. Brown and sandy loam prairies.
   e. Long-leaf pine hills and flats.
   f. Upper and lower cross timbers.
2. Southern and coast prairies.
   a. Country east of the Brazos.
   b. Country west of the Brazos to the Nueces and Frio rivers.
   c. Southwestern prairies and sandy desert.
3. Central black prairie region.
4. Northwestern red loam lands.
5. Western and Northwestern region.
   a. Gypsum lands.
   b. Llano Estacado, or the Great Plain.
   c. Mountain region.
6. River alluvial lands, including the Brazos delta, or Sugar-bowl.

Every cotton grower in the Central black prairie region has had more or less experience with the "dying of cotton," and in a general way it is quite correct to say that cotton dies in nearly every county in this region, but it is erroneous to suppose that parts of the State outside of this region are not troubled with the disease, for in some of the chief cotton growing counties lying considerably south of this belt, as in Washington, Grimes, Colorado, Austin and Fayette, fully one-third of the cotton dies on some of the plantations. Thus far I have observed "cotton dying" in the following counties: Washington, Grimes, Fayette, Brazos, Waller, Travis, Hays, Limestone, Williamson, Milam, Burnet, Robertson, Grayson, Collin, Ellis and Dallas. In addition to this Captain T. M. Scott informs me that he has observed it in Denton, Collin, Grayson, Dallas, Fannin, Lamar, Tarrant, Grimes, Waller and Brazos, and Mr. W. Wipprecht in Comal, Kendall and Bexar.

According to Dr. H. H. Loughridge[4] in Red River, Hopkins, Titus, Cass, Bastrop, Lee, Trinity, Cherokee, Anderson, Fannin, Wise, Hamilton, Bass, Bosque, Hill.

4. Tenth Census Report, Vol. V., Pt. I, p. 158.

Mr. T. P. Yale, of Columbia, Brazoria County, writes me that the disease is seldom troublesome along the gulf.

According to Mr. T. B. Baldwin it is not common about Marshall, in Eastern Texas. [5]

In the early part of August I made some field studies of the disease in Travis, Hays and Burnet counties. In all of these cotton is more or less subject to Root Rot, but far less so in the broken and hilly country about Burnet than in the open and prairie country of Hays and Travis. However, according to Mr. Ramsey, it does considerable damage near Mahomet. A glance at the agricultural map of Texas will show at once that most of the enumerated counties lie in the cotton belt, and moreover are in the central black prairie region, excluding the alluvial bottoms along the Brazos and Colorado rivers, where cotton is seldom subject to this "dying in spots." On this point, however, opinions differ somewhat. Many claim to have found the disease on bottom plantations. J. P. Stelle [6] has observed it, but he does not give localities. Capt. A. W. Felker, of Hempstead, who has a large plantation in the Brazos bottom, entertained a similar opinion, but he has informed me that it was not in the real alluvial bottom, but rather on "second bottom" and Post Oak lands where cotton "blighted." On the plantations of Rogers and Hill, at Allen Farm, I could not find a single stalk which in any way was affected with Root Rot, though some of the land had been in cultivation for many years. Nor did I succeed in obtaining diseased materials from the bottom plantations, near Calvert, although Mr. E. S. Peters and I made a thorough search. The disease, however, was found on "second bottom" and Post Oak lands bordering on the alluvial bottoms. The greater part of the region where Cotton Root Rot appears belongs to the geological formations known as the cretaceous, and the underlying stratum is usually a rotten limestone, which, as is well known, is not readily permeable to water. The so-called "hog-wallow" lands are common in this region, and cotton is said to die more frequently on these than on any other kind of soil. The black sandy prairie lands are also plentiful in the cretaceous of Texas, and are underlaid in many cases by an impervious and water-holding clay, as are also the so-called Post Oak lands of the timbered upland region of Eastern and Central Texas. On all of

5. The disease also occurs in Mississippi according to Galloway Hilgard; and in Florida according to Barbee (The Cotton Question, p. 241), and I have seen it near Caddo, Indian Territory.

6. Fourth Entomological Report, Appendix III., p. 25.

these, cotton is more or less subject to this disease, although in not so marked a degree as in the black prairie region.

The drainage of much of the Post Oak lands must necessarily be poor, and this is especially true of the so-called "Post Oak flats."

Dr. H. H. Loughridge,[7] in speaking of these says: "The surface of the region between Houston and Hempstead is very level and even, with a descent so gradual as to afford no drainage to the soils. As a natural consequence water remains in pools upon the prairies of the region until removed by evaporation."

Between Millican and Bryan I have seen a number of these "Post Oak flats." At College Station an impervious and tenacious clay is found from three to six inches below the surface, yet no where in this vicinity did I find "cotton dying." During dry seasons this soil is especially subject to drouth.[8]

The first indication of the disease south of College Station is at Millican, on black sandy lands—in some places partaking of the nature of the black waxey soils—and on the adjoining Post Oak lands. From the distribution of the disease and the character of the soil upon which it occurs, it would seem that moisture is a predominating cause. But it is an open question why the stiff and undrained bottom land of the Brazos does not show the disease, unless it be due to the great fertility of the soil, but according to Dr. Hilgard bottom lands show "Cotton Blight" badly, at least in Mississippi. In regard to this trouble and drainage he writes me as follows: "I think 'Cotton Blight,' or rather a large proportion of what is currently so-called, is due to undrained soils of a heavy type. The worst cases I have seen occurred on the tertiary and cretaceous formations of Mississippi, in the stiff, yellow hog-wallow soils. On investigation I always found the tip of the root diseased, and whether the fungus precedes or follows the damage to the nutrition and progress of the root is hard to say, but its appearance is certainly connected in a very large number of cases with a reaching of an undrained and impervious subsoil."

Numerous theories have been advanced, and it is proper that they receive some attention. Much prominence is given to the idea that certain chemical or physical conditions of the soil cause the root to decay, and therefore many believe that the question cannot be

7. Tenth Census Report, Vol. V., Pt. I., p. 30.

8. Prof. F. H. King, to whom I communicated the case, writes me as follows: "In the case of the Post Oak lands of Texas, underlaid by a stratum of impervious clay, it may be that this stratum tends to prevent the rise of water through it by capilary action faster than the evaporation above can remove it, and thus give you really dryer soil than you would otherwise have."

solved in any other way excepting a comparative chemical analysis made of the soil found in the so-called "dead spots" and those where cotton does not die. A careful chemical analysis of the soil made by Mr. W. Wipphrecht does not show any appreciable difference in the character of the soils. (See analysis of Soils, Chemist's report.)

Dr. F. L. Yoakum [9] believes there is an excess of sulphuric acid in the soil, which is formed by the decomposition of Sulphide of Iron (Pyrites) when, through the influence of sunlight and air Sulphate of Iron (Copperas) is formed, which is not only destructive to man, but also to vegetation. This Sulphide of Iron is deeply situated in the earth, and is brought to the surface through cultivation. In that way sunlight and air can act upon it and bring about the changes described. Consequently new fields seldom "blight" as much as old ones. The spots grow wider and wider as the Sulphate of Iron increases.

The analysis made by Mr. Wipprecht show only traces of sulphuric acid in a few cases. I made some experiments with copperas and cotton, using a 2.5 per cent. solution, but cotton was not killed from its use.

Many are of the opinion that an "alkali" brings the destruction about. The term is somewhat vaguely used. "Alkali" commonly designates an efflorescence of a white powder or crust on the surface of the soil, which is readily soluble in water. Dr. E. W. Hilgard[10] who has given the subject of "alkalies" considerable attention, especially those of California,[11] says, cotton does admirably on it, and is especially to be recommended, as fibrous rooted plants like cereals are especially subject to die from the effects of "alkali." "More and more every year the 'dead spots' in wheat fields increase, and when, on account of such failures, it ceases to be profitable, something else must be substituted, and that substitute must be a hoed crop, planted in drills and capable of being cultivated at all times. It should moreover be a deep and tap rooted crop, requiring the least amount of irri-

9. Texas Farm and Ranch, October 7, 1886.

10. Tenth Census Report, Vol. VI., Pt. III.; Special Report California, p. 63. "The immediate source of "alkali" is usually to be found in the soil water, which, rising from below and evaporating at the surface deposits there whatever of dissolved matter it may contain. Such water, when reached by digging, is by no means always perceptibly salty or alkaline, and the same is mostly true of the soil an inch or two beneath the surface; for since the soil, acting like a wick, draws up the soil water and allows it to evaporate at the surface, it is there, of course, that all of the dissolved matters accumulate until the solution becomes so strong as to injure or kill all useful vegetation. The injury will usually be found to be most severe just at or near the crown of the root where the stem emerges from the ground."

11. L. C., p. 11.

gation on account of the depth to which its roots reach. Cotton fulfills pre-eminently both conditions." In Texas, where Root Rot of Cotton is so prevalent, plants of the grass family do exceedingly well on the so-called "dead spots."[12] At any rate they are not subject to Root Rot, so far as I know. On numerous diseased cotton stalks examined not a single one was found in which the severest point of attack was at the crown, or near the surface of the soil, as is said to be the case in fibrous rooted plants when killed by "alkali."[13]

In parts of the state farmers believe that Root Rot is caused by an excess of lime in the soil. The idea probably originated because much of the prairie soil contains a great deal of lime. That this is not the cause of the trouble becomes very evident where limestone crops out on a ridge—on one part cotton is dead, and on the other in good growing condition.

In Washington and Grimes counties some soils are designated as "shelly lands," because of the great abundance of snail shells[14] found there. It is claimed that by the decomposition of these shells cotton is killed. Snail shells are equally common where cotton is not killed, as on the bottom plantations at Allen Farm and Calvert. Even in the same field in Washington and Grimes counties these differences can be seen. Snail shells contain a large percentage of lime. It is well known that lime acts as a valuable agent in rendering available some of the mineral elements of the soil, and is especially important in the process of nitrification.

In 1878 Mr. A. M. Ramsey,[15] of Burnet county, sent soils to Hon. Norman J. Colman with the request that an analysis of the soils be made. This communication was replied to by J. M. H., in which he gives a report from Ryland M. Brown, of Washington, D. C., on the chemical analysis of soils from Collin county. A chemical analysis showed the entire absence of sulphuric acid or any other sulphur compound. A large percentage of humus, which probably exists as humic acid and in combination with alumina and iron, forms insoluble humates of these bases, which accounts for the very small amount of soluble matter in the soil. In a clay subsoil charged with water to a point of saturation, the organic

12. Except in South Texas, where wheat, oats and rye are said to rust badly.
13. There are "alkali" soils in Texas, as Dr. Loughridge has shown.
14. Two of these have been identified for me by Dr. Hambach as *Balimulus dealbatus* and *B. Schleidianus var. Moorianus*.
15. Colman's Rural World, April 8, 1878.
16. Colman's Rural World, May, 1878.

matter will be converted into carbonic acid, ammonia and water, which a free exposure to the air will effect. This explains also the fact that crops which draw their nutriment from the soil by superficial roots are not unfavorably affected in these spots, "The surface soil being more exposed to the air and less subject to saturation."

Like many others this writer believes that the roots of cereal crops derive their mineral elements entirely from the surface soil, and thus are not affected. In Texas where the conditions of soil and atmosphere are so different from those in such States as Illinois, Missouri or Arkansas, these plants obtain much of their mineral elements at some distance from the surface. Very often the surface soil is hard and compact for several inches, and thus the roots are forced to go down deeper for their food. It is a well established fact that the fibrous roots of wheat, oats, corn, and other grasses often penetrate the soil from three to five feet, depending somewhat on the character of the soil, and even through hard and stiff clay.[17]

Dr. H. H. Loughridge[18] has advanced the theory that dying in spots is chiefly produced either by lack of drainage or by some cause that arrests the extension of the tap-root downward in its search for moisture. "A tap-root of the cotton plant is known to penetrate many feet in the earth, and it is not at all improbable that an impervious stratum of clay or limestone may be reached by a large number of plants, or that a rock may be in the way of a single root, thus producing the decay of a large area of plants, or of a single plant." It is well known to every cotton grower that young cotton plants when injured are especially liable to succumb. And for this reason many believe that the tap root in its descent downward comes in contact with hard and compact material and as a result decay follows. I have frequently found a number of lateral roots of equal strength. The main root was evidently stopped or injured in some way, hence, the production of these lateral roots. That individual plants are killed here and there by mechanical injuries no one will dispute, but that a large area can be destroyed in this way is questionable.

At White Hall and Independence I took pains to determine the

17. Those who are interested in this subject will find numerous examples and references to the literature in Agriculture and some of its Relations to Chemistry by F. H. Storer, Vol. II., p. 175. Grasses of North America for Farmers and Students by W. J. Beal, Vol I., p. 3 and 253. H. P. Armsby, Root Development of Corn, Report of Penn. State College, 1887, Pt. II., p. 90.

18. Tenth Census Report, Vol. V., special report Texas, p. 53.

depth at which a solid stratum of rock was reached, to see whether differences could be found in the amount of cotton dying. In the former place the strata varied from four to six feet, in the latter from four to eight feet, yet no appreciable difference could be seen. While the roots of cotton undoubtedly reached this depth, little injury can result, for Darwin[19] and other investigators have shown that the tips of roots are wonderfully sensitive, and follow the line of least resistance. If the roots of cotton find obstructions such as a stone they are easily deflected from their course, or if a solid stratum of rock offers resistance the root would naturally spread over it. In many hundred specimens of cotton roots examined, I have seen so many in which the tips of the roots were healthy, so far as microscopic examinations showed, that I cannot believe a rock obstruction causes decay of the tip.

The theory that insects destroy the root has many followers, but after a thorough examination of a large number of these roots I am convinced that they do not cause the trouble, and in this connection it will be interesting to refer to Prof. C. V. Riley's[20] Cotton Worm and Boll Worm Report, in which J. P. Stelle has a short account of this disease. Mr. Stelle felt confident that insects in no way caused the disease. Mr. L. O. Howard, of the United States Entomological Department, writes me that the department entomologists had always supposed the disease to be due to a fungus and not to insects.

I have frequently found nematodes and mites, such as are common in putrefactive substances. I never found these present unless the root was in a decaying condition. I was frequently told that small holes had been found in the tap root—that these were made by insects. On examination it was found that in pulling up decayed roots, the small lateral rootlets remained in the ground, thus causing small holes to be found in the root.

There still remains but one theory to discuss, the so-called "fungus theory." Few persons believe it to be due to a parasitic fungus. Mr. A. W. Kerr, J. B. Stephens and others take this view of the question.[21]

Before discussing the nature of the disease it will be necessary to decide on some common indicative name by which the disease ought to be known, so as not to cause confusion. Many cotton

19. Charles Darwin—The Power of Movement in Plants, Chapter 12, p. 546.

20. C. V. Riley.—Fourth Report of the United States Entomological Commission; on the Cotton Worm and Boll Worm, Washington, D. C., Appendix III., p. 25.

21. Texas Farm and Ranch, September, 1886, and January 1, 1888.

growers will not sanction any term but "Cotton Blight." The term "Blight" is applied to an entirely different class of diseases —such, for instance, as the "Cotton-leaf Blight," "Strawberry-leaf Blight," etc.

The term "Cotton Blight" is frequently used to designate Cotton Rust, and, unless a description follows the use of the word, one is at a loss to know what is meant. The term "Frenching" is also used, but it is ill chosen, for in parts of the South certain cotton sports which produce white and yellow variegated leaves are said to "French." [22]

The terms "dead spots" or "dying of cotton" are not inappropriate, but they do not designate any particular disease. "Root Blight" has also been used, but as this term would carry with it a mistaken idea it would be better to use the term Pourridie, or "Root Rot of Cotton." Two competent observers, Profs. Viala and Scribner, who observed the dying condition of cotton in Texas, designated it as a root rot, and it seems to me this is the proper term to use.

Prof. Viala [23] defines Pourridie as the alteration of the roots which proceeds from the direct action of parasitic fungi, and should not be extended to those special cases in which rotting of the organs comes indirectly from purely accidental or physiological causes.

Pourridie, or Root Rot, as a parasitic disease, due to a fungus,[24] has only been conclusively demonstrated within recent years. Some important contributions to the subject were made as early as 1855. At this time Dr. Julius Kuhn [25] and others called attention to a very serious Root Rot of Alfalfa, Carrots and Mangolds, due to the Violet Root Fungus, *Rhizoctonia violacea.* In all these cases plants die in patches like cotton, such patches the Germans designate as "Fehlstellen." The Crocus [26] and Hyacinth are subject to several Root Rot diseases.

22. In the South the term is also applied to corn, where it grows light-colored—some times almost white or striped, and bears no crop.

23. Les Maladies de la vigne, p. 334.

24. Fungus (plural, fungi) is a plant of low organization, having a vegetative and reproductive system, destitute of chlorophyll, the green coloring matter found in leaves and other parts of plants. By the aid of chlorophyll plants are enabled to carry on assimilation—that is, to make their own food. All of the algap, which are closely related to fungi, most of the flowering plants, ferns, mosses, liverworts have chlorophyll, hence can make their own food. Fungi are parasitic when they feed on living plants or animals; saprophytic when they derive their nourishment from dead or decaying organic substances. Wheat and oat rust, smut of corn, bunt of wheat, pear blight, etc., are caused by parasitic fungi. Most of the toad stools, puff balls, putrefactive bacteria are saprophytic.

25. Die Krankheiten der Kulturgewachse, ihre Ursachen und ihre Verhutung, Berlin, 1858, p. 245 and 236.

26. A. Massink —Untersuchungen uber Krankheiten der Tazetten und Hyacinthen. Sorauer, Handbuch der Pflanzen Krankheiten, etc.

In 1874 Dr. Robert Hartig,[27] of Munich, published a remarkable and interesting paper, showing that Pourridie of conifers is due to one of the fleshy fungi (*Agaricus melleus*). After the appearance of this publication investigators began to study Pourridie of the vine. In 1877 Schnetzler[28] called attention to the fact that in France, Germany and Switzerland a destructive disease was prevalent, which was not caused by Phylloxera, but was attributable to a parasitic fungus. He ascribed the cause to the Rhizomorpha of *Agaricus melleus*. Hartig, however, has shown that the Rhizomorpha found by Schnetzler was different from that which develops into *Agaricus melleus*, and the injury the latter does to the roots of the grape vine is certainly very much restricted. In the same year Von Thuemen[29] published an account of a fungus, *Roesleria hypogaea*, now called *Vibrissea hypogaea*, which he thought caused Pourridie of the vine. A number of observers, notably Prillieux,[30] Millardet,[31] A. D'Arbois de Jubainville,[32] believe this fungus to be a real parasite.

It is still an open question whether this fungus lives merely as a saprophyte or is a parasite causing Root Rot. Dr. Hartig, whose opinion has great weight, believes it to be entirely saprophytic.[33]

The latest and most important contributions on the subject of Pourridie of the Vine have been made by Hartig[34] and Viala,[35] who have shown that in most cases it is due to *Dematophora necatrix*.

I have referred to the literature of the subject at some length, although by no means complete, because it is important that every phase of this disease should be considered somewhat carefully. Before passing to a botanical consideration of Root Rot of Cotton, mention should be made of the Root Rot of apple trees, as in Texas

27. Wichtige Kranheiten der Waldbaume, 1874, p. 12-43, Pt. I.-II.

28. Observation faites sur une maladie de la Vigne connue vulgairement sous le nom de Blanc, Comptes-rendus, 1877.

29. Die Pilze des Weinstockes, 1878, p. 208.

30. Le Pourridie des Vignes de la Haute-Marne. Ann. Inst. Nat. Agronomique, 1882, p. 171, Pt. I.

31. Pourridie et Phylloxera etude comparative de ces deux maladie de la Vigne, Paris, 1882.

32. Les Maladies des Plantes Cultivees des arbres fruitiers et forestiers produites par le sol, l'atmosphere, les parasites vegetaux, etc., Paris, 1878.

33. I have found this disease at Ennis, Tex., and Profs. Viala and Scribner have also found it in Texas, Missouri and California. F. L. Scribner—Report of the Chief of the Section of Vegetable Pathology, 1887, p. 324.

34. Rhizomorpha (Dematophora) necatrix Untersuchungen aus dem Forst-botanischem Institut zu Muenchen, II. Berlin, 1883, p. 95-140, with two plates. Der Wurzelpilz des Weinstockes *Dematophora necatrix*. R. Hotg, Berlin, 1883.

35. Les Maladies de la Vign Montpellie, 1887, Chapter on Pourridie, p. 334, where a very full literature of the subject is given. I am much indebted to Prof. B. T. Galloway for a translated copy of this chapter.

it is quite a serious trouble. There can be no doubt, from what I have observed, that several different fungi play an important part in destroying the roots of trees. Nothing definite, however, has been done to show that fungus causes a rot, excepting that different fungi are frequently found associated with dying trees.

Mr. F. S. Earle[36] believes there is little doubt that one of the commonest of fungi belonging to the family of toad-stools, *Polyporus versicolor*, causes Root Rot of pear trees in Illinois.

GENERAL CHARACTERS OF THE COTTON DISEASE.

The general appearance of plants affected with this disease is familiar to many. The first thing observed is the sudden wilting of plants here and there in the fields, which become dry from twelve to twenty-four hours. This appearance is usually first noticed in the latter part of June, and continues till frost. I am inclined to believe that the disease makes its appearance very much earlier, even attacking very young plants. Mr. R. D. Blackshear writes me that he has observed it early in May; that it does not appear until cotton has reached a half grown stage; this is easily accounted for, if one considers that at first only a single plant dies here and there in the field, and presumably many believe such plants to have been killed by mechanical injury.

Somewhat later, however, when the infection has spread to neighboring plants, and a number are suddenly found to wilt, the planter's attention is called to them. That a great many more plants die suddenly when bolls are forming than earlier in the season is to be expected, since much elaborated material is required for developing fibre and seeds. Starting from a single dead stalk in May or June by the end of July or in August patches or "dead spots" of considerable size may be found, which show no regularity whatever. Sometimes the patches run in a zig-zag way through fields, with intervening healthy plants.

It is well know that healthy looking plants are found in close proximity to dead stalks, which is frequently urged as a reason why the disease cannot be due to a parasitic fungus. It is more than probable that certain plants will not take the disease, or that in some way the spores or mycelium did not reach the root. Prof. Watkins has sent me such specimens collected as late as the 10th

36. Pear diseases caused by fungi, from Transactions of Illinois Horticultural Society, Vol. XX., 1886, p. 168.

of November. There is no doubt, however, that some plants, which are apparently exempt early in the season, take the disease later.

If the root of a wilted cotton plant is examined immediately after a rain, or those portions of it from moist soil, a dense mass of sterile mycelium will be found, and in numerous places small protuberances. This has been identified as *Ozonium auricomun*, Lk.[37]

Everywhere this fungus is found associated with the disease, and in such a way as to make it appear as the probable cause of Root Rot of Cotton. There can be little question that the *Ozonium* is a true parasite, as the mycelium or vegetative part of the fungus is found, not only in the bark but also in the medullary rays and vessels. A cross section through one of the small protuberances or pseudosclerotia, shows that it penetrates through the bark into the wood tissue. At Millican, San Marcos, Austin and Ennis a large number of both wilted and apparently healthy plants were taken up, the roots carefully examined, and on a number of the apparently healthy plants portions of the root showed a whitish mycelium, having the same structure that the yellowish-brown mycelium of the *Ozonium* has. On cross sections of these roots it was found that the vessels were filled with this mycelium. On the younger roots of wilted plants the white mycelium frequently preceded decay.

The *Ozonium* is found in great quantities on the sweet potato.[38] On an apparently healthy potato a number of depressions were found in the center of each a little protuberance or pseudosclerotium, similar to those on cotton. The surrounding tissue was undergoing decay. In others the yellowish-brown mycelium of the *Ozonium* covered the greater part of the potato; one end was almost entirely decayed. Near the undiseased part tissues were still firm, but contained an abundance of mycelium. On the roots of cotton, as a result of the fermentation set up by the fungus, red discolorations, which ultimately change to brown, are formed.

The point where the disease stops is usually sharply defined by an enlargement formed through the shrinkage of the bark below, and the storage of elaborated material at this point.

As stated before, the sudden wilting of plants is one of the chief characters of the disease, and is brought about in the following way:—The elaborated material found in the leaves is checked

37. Dr. W. G. Farlow has kindly identified the fungus for me.

38. I am indebted to Prof. J. C. Watkins and Mr A. W. Kerr for a fine lot of material.

when the disease is in progress, and thus cannot supply the roots with nourishing materal to develop new roots and root hairs. Nor can the water and mineral elements absorbed by the roots and root hairs reach the leaf for assimilation.

Frequently a diseased plant develops a number of lateral roots above the diseased part. Thus the plant can maintain itself through a period of drouth; but when wet weather sets in such plants quickly succumb, owing to the rapid growth of the fungus.

THE INFECTIOUS NATURE OF THE DISEASE.

This is amply proved by a large number of cases. It is universally admitted that where the disease is once established, cotton dies year after year unless checked. The "dead spots" increase in size. When such plants as Sweet Potatoes, Grapes, Mulberry, Apple, China trees and Cow Peas follow diseased cotton they also die in the same way, namely, a rotting of the roots occurs. As an illustration Iwill only give one case, which came under my personal observation: I was anxious to obtain sweet potatoes which showed Root Rot. My desire was expressed to Mr. A. W. Kerr, of Sherman. I was shown a sweet potato patch, in the center of which a Red Mulberry tree died last year from Root Rot. Here we found an abundance of material; some of the potatoes were entirely decayed; others only in part. In every case the *Ozonium* was present.

The fungus nature of the disease has been described here in a general way. In a final report I hope to show conclusively by making inoculation experiments on cotton grown in sterilized soil watered with spores of the fungus; whether this is the cause, or merely a saprophyte living on altered organs. I hope also to be able to give an account of the life history of the fungus and other interesting points which have come up in the study of the disease.

TREATMENT.

It will be somewhat difficult to treat this disease. The application of fungicides at a time when the disease is in progress will do little good, for the external characters do not show till the plants are too far gone to be affected by treatment. Moreover a fungus working in the tissues of the plant, as *Ozonium* does, would be hard to get at. In treating a diseased plant, where the mycelium is found in the tissues, the application of fungicides might impair

the vigor of the plant or destroy it wholly. The only practical method of dealing with the disease, therefore, will probably be found in certain preventives. First of all the spores and fungus threads which transmit the disease through the soil from plant to plant must be destroyed. In the case of Root Rot of the Grape, it has been recommended to dig ditches around the affected areas. In case of cotton this would be impracticable, but it could be done with advantage in orchards and vineyards. As the spores and mycelium are found on decayed cotton stalks, the removal of these is essential. The best method would be to burn every infected stalk in the field where found. If diseased stalks are carried from field to field, the spores and fungus threads are liable to fall off, and new infected areas may result.

It has been shown that moisture is a predominating cause. A thorough drainage of the soil would probably do much good, but only after the disease has been entirely eradicated from the soil. There seems to be pretty good evidence that fertilizers, in a measure, prevent the disease, as the following goes to show: Near Brenham, on Post Oak land, a field was found, two acres of which received a heavy dressing of stable manure two years previous. Here very little dead cotton was found. The soil adjoining this patch was identically the same, so far as one could tell from a superficial examination, yet nearly one-third of the cotton was dead. Mr. Peters pointed out to me a similar case near Calvert. Mr. R. D. Blackshear says, in regard to the use of fertilizers to prevent Root Rot: "In 1886 I used cotton seed meal in a little patch in front of my house, and the result was a bale of 511 pounds per acre and very little 'dying out' seen anywhere." It should be stated that in all these cases vigorous and strong plants were found. I think from a practical point of view a proper method of rotation of crops is the best way to destroy the fungus. Not only has this been shown in field studies, but the practical cotton growers of the State are nearly unanimous on this point. Aside from the well established principle that different crops do not affect the soil in the same way, it is important to rotate to destroy insects and fungi, which live on particular hosts. Thus gardeners find it difficult to grow cabbage two years in succession, in many places, on account of a fungus disease called "Clump Foot." In rotating care must be taken not to follow cotton by plants which are subject to Root Rot. Thus, as is well known, sweet potatoes, cowpeas, apple trees, grape vines and many of the forest trees are subject to this disease, con-

sequently ought not to follow cotton when Root Rot has established itself. Certain weeds are also subject to the disease, hence fields ought to be kept rigidly clean. So far as is known the fibrous-rooted plants, such as corn, oats and wheat, are exempt from the disease, and where practicable these should follow cotton. It has been urged that in Southern Texas wheat rusts so badly that it will be impossible to use these plants; instead, sorghum, millet, corn and oats might be used to advantage. In North Texas, where small grains are a certain crop, rotation is often resorted to to prevent the "dying of cotton." As an illustration: Four years ago considerable cotton was killed by Root Rot in a field of Mr. Ormsby Scott, near Melissa. Since that time the field has been planted in corn, oats and wheat, and the present year in cotton. On the first of September very little dead cotton was found in that field. Similar cases have been found at Plano, San Marcos and Independence.

A more striking difference is shown if a comparison be made between such counties as Dallas, Collin and Ellis, in North Texas, with those of Grimes, Washington and Fayette, in South Texas. A much larger percentage of dead cotton will be found in the latter counties. The reasons are obvious; in South Texas cotton is frequently grown for four or five and even ten years on the same field.

The length of time before cotton can be grown successfully in fields where Root Rot has established itself is a matter which only experience can decide. Mr. H. R. von Bieberstein recommends for South Texas a three year rotation, using oats, corn and millet. The point to be aimed at in all cases is the destruction of the fungus, as in certain stages, the *Ozonium* probably lives as a saprophyte, and thus is capable of maintaining itself for one or more years. That a simple alternation of crops is not sufficient is well illustrated in the following cases: At Independence, Captain Tom Clay pointed out a number of fields to me which had been in corn the year before, yet cotton was dying quite severely.

Some urge as a remedy the planting of corn and cotton in alternate rows. Dr. Waters informs me that he has seen it tried with success. Several fields of this kind came under my observation, but cotton was dying at the usual rate. These may not have been fair tests.

In conclusion it becomes my pleasant duty to thank those who have assisted me in prosecuting the studies of this disease, especially:

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