Illustrated fig. 2, Plate 1.

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COTTON ROOT-ROT

AGRICULTURAL AND MECHANICAL COLLEGE,

College Station, Brazos County, Texas.

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COTTON ROOT-ROT.

In a preliminary bulletin on "Root Rot"[1] a brief account of the character of the soil, some of the theories, and the fungous nature of the disease was given. To make the account of this disease as nearly complete as possible, some of the facts already published will be used in this report.

Planters quite generally believe that the character of the soil has much to do with the disease,[2] but from observations in the field for two seasons, and the answers received to a circular postal card sent out by the Station, it is evident that nearly all classes of soil are more or less subject to it, though the alluvial bottoms of the Brazos and Colorado rivers. and the Gulf prairie region near the coast, are exempt so far as I can learn. It occurs, however, in the northern tier of counties of the Gulf prairie region, as in Washington, Fayette, and Austin. It is, then, in the central black prairie region of Texas and just south of it where planters suffer most from the disease.

Its northern boundary is the Red River as far east as Paris, Texas, extending in a southwesterly direction to San Antonio and thence westward. Its western boundary in the north is Montague, Wise, Parker, and Hamilton counties. A white rotten limestone, which often crops out, underlies the entire region. The soil of these rolling and black waxy prairie lands is very retentive of moisture, especially so when limestone comes near the surface. A certain amount of moisture is essential for the growth of the fungus. It is not uncommon to see cotton dying on these limestone ridges and slopes when none is affected in any other part of the field. On these limestone slopes I have frequently noticed that water collects in the form of drops on the tap-root. But it must be borne in mind that cotton is not always affected in such places.

The character of the forest growth is frequently mentioned as indicative of the disease, thus hickory, sumach, shittim, mesquite, and post oak are all said, in localities where these trees abound, to be associated with the disease. Careful investigation has shown that they are not at all indicative. Though the live, post, and black jack oaks, osage orange, prickly ash, pecan, mesquite, and others are found on particular soils, the disease occurs alike on the live oak glades of Washington county, on the post oak soils of Eastern and Northern Texas, and on the osage orange soils of Grayson, Collin, and Dallas Counties, or on the mesquite soils of Milam, Travis, and Hays Counties.

It will be seen from the list in the foot note[3] that the character of the forest growth of the different regions is not alike, yet in each case the disease occurs.

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[1] Texas Agricultural Experiment Station Bulletin 4, p. 18; also first Annual Report, p. 50.

[2] 1. The timbered upland region of East and Central Texas, including the Upper and Lower Cross Timbers, pineries, long leaf-pine hills and flats.
2. Southern coast prairies.
3. Central black prairie region.
4. Northwestern red-loam lands.
5. Western and northwestern region, including gypsum lands, Llano Estacado or Great Plain, and mountain region.
6. River alluvial lands, including the Brazos delta and Sugar Bowl.

[3] The trees in this list were found growing in close proximity of dying cotton. Washington County is in the Gulf prairie region, and the following trees were noted: Water Oak (*Quercus aquatica*, Walt.), Live Oak (*Q. virens*, Ait.), Black Jack (*Q. nigra*, Linn.), Post Oak

THEORIES.

It is not surprising that theories of various kinds should be formulated to account for the sudden dying of cotton. Much prominence is given to the idea that certain chemical or physical conditions of the soil cause the root to decay, and therefore the subject of "root rot" can not be solved in any other way except by a chemical analysis; but a careful chemical analysis of affected and not affected soils does not show any appreciable difference so far as its makeup is concerned.[4]

Dr. Yoakum believes that the "dying of cotton"[5] is due to an excess of sulphuric acid in the soil, which is formed from sulphide of iron which exists everywhere in Texas. Sunlight and air acting on sulphuric acid form sulphate of iron, which is destructive, not only to man, but to vegetation also. But analysis made at the Station by Mr. Wipprecht, and those given by Hilgard[6] in his report on Cotton Production, only show traces or small amounts of sulphuric acid. Experiment has shown that a two and a half per cent solution of copperas does not act injuriously on the roots of cotton. Many believe that an excess of lime in the soil causes death of the plant. In some cases the percentage of lime in the affected land is high, as at San Marcos. At Independence it is just the reverse. Lime as it exists in the soils of Texas can do little injury to vegetation. It is, moreover, a very valuable ingredient of soils, being especially important in the process of nitrification.

In Washington and Grimes counties snail shells abound in the prairie soils, but also in the alluvial bottoms of the Brazos. In the prairie soils where they exist the shells are supposed by decomposition to cause death of the cotton root. These shells are made up largely of calcium carbonate, which, as stated before, is a valuable ingredient of soils. Not a single cotton plant at Allen Farm, or in the Brazos bottom opposite Washington, or at Calvert, dies from this disease, though snail shells are exceedingly common. An analytical chemist attempts to account for the disease as follows: Sulphuric acid is absent, a large amount of humus, which in the fresh soil exists as humic acid, in com-

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Q. obtusiloba, Michx.), Hackberry (*Celtis occidentalis*, Linn.), Cedar Elm (*Ulmus crassifolia*, Nuttall), Yaupon (*Ilex Cassine*, Walt.), Prickly Ash (*Xanthoxylum Clava-Herculis*, Linn.), Persimmon (*Diospyros Virginana*, Linn.), Shittim (*Bumelia lanuginosa*, Ait.), Hickory (*Carya tomentosa*, Nuttall), Mock Orange or Cherry-Laurel (*Prunus Caroliniana*, Ait).

In the timbered upland region of East and Central Texas, in the counties of Grimes, Brazos, and Robertson: Oaks (*Quercus aquatica*), (*Q. obtusiloba*), (*Q. nigra*), Spanish Oak (*Q. falcata*, Michx.), Cotton Wood (*Populus monilifera*, Ait.), Red Mulberry (*Morus rubra*, Linn.), Black Walnut (*Juglans nigra*, Linn.), Pecan (*Carya olivæformis*, Nuttall), *C. tomentosa*, *Diospyros Virginiana*, Sumach (*Rhus copallina*, Linn.), Honey Locust (*Gleditschia triacanthos*, Linn.), *Bumelia lanuginosa*, Mesquite (*Prosopis juliflora*, D. C.)

In Burnet, Travis, and Hays Counties: *Prosopis juliflora*, *Rhus copallina*, Linn., *var. lanceolata*, Gray., Mexican Persimmon (*Diospyros Texana*, Scheele), *Celtis occidentalis*, Barberry (*Berberis trifoliolata*, Moric), *Quercus obtusiloba*, *Q. lyrata*, Red Cedar (*Juniperus Virginiana*, Linn.), *Ungnadia speciosa*, Endl., *Ilex decidua*, Walt.

In Ellis, Dallas, Grayson, and Collin Counties of the central black prairie region: Red Bud (*Cercis Canadensis*, Linn.), *Gleditschia triacanthos*, *Rhus copallina*, Dogwood (*Cornus painculata*, L'Her.), Chicasaw Plum (*Prunus Chicasa*, Michx.), *Diospyros Virginiana*, *Bumelia lanuginosa*, *Celtis occidentalis*, *Sassafras officinalis*, *Juglans nigra*, Sycamore (*Plantanus occidentalis*), *Carya olivæformis*, *Ulmus crassifolia*, Bois d'Arc or Osage Orange (*Maclura aurantiaca*, Nuttall), *Morus rubra*, *Populus monilifera*, *Sapindus marginatus*, *Ilex decidua*, *Xanthoxylum Clava-Herculis*, *Juniperus Virginiana*, *Quercus lyrata*, *Q. obtusiloba*, *Q. nigra*, *Q. Michauxii*, Nuttall, *Crataegus sp.*

[4] First Annual Report of Texas Agricultural Experiment Station, p. 24.

[5] Texas Farm and Ranch, October 7, 1886.

[6] Tenth Census Report, Cotton Production, vols. 5 and 6.

bination with alumina and iron forming insoluble humates of these bases. Where the subsoil is saturated with water for a portion of the year the usual decomposition into carbonic acid, ammonia, and water will not take place, but instead humic acid will be found. The surface soil being more exposed to the air is not so saturated, hence humic acid will not be formed, and therefore surface rooted plants are not subject to the disease.

Mr. Wellborn's views are given below:[7]

"We know that on swamp lands or ponds when first drained the vegetable matter in the soil and subsoil has too much acid by being submerged, where the air could not penetrate, but when exposed to the air it sweetens; so the surface is in condition to start vegetation, but of course the deeper the longer it takes. It takes several months' air to sweeten when it has fair play at it; but if air can not penetrate the soil on account of either excess of water or compact condition of the surface, how can it be sweetened? And of course, as the humus is taken from the surface soil by plants, it cements or runs together more closely. This would naturally bring the acidity nearer the surface, and would cause the root rot to commence earlier and be more severe. If the land cannot be thoroughly drained it should be kept in beds or ridges, with deep furrows run deep in the water furrows as soon as convenient in the spring, and use manures or fertilizers containing nitrogen or potash, or both. Bury them as deep as possible under the beds when heading up, which should be done during fall if convenient, and before the subsoil saturates with water. It seems that the blight confines itself almost if not wholly to the 'hog wallow prairies' and 'post oak flats.' It is evident that both the prairie and flats have, in times past, received an excess of vegetable matter, but still the surface is hard and compact instead of loose and friable, as soils filled with humus and which have perfect drainage should be. But where this vegetable matter is submerged eight months out of twelve, instead of turning into plant food (ammonia) it must turn into acids and eat off the roots. We see that timber on swamp lands keep all their roots near the surface, occasionally showing above ground."

Dr. Loughridge[8] accounts for the "dying of cotton" either through 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 cotton, in its search for moisture, penetrates the earth many feet, and it is not improbable that it may come in contact with an impervious stratum of clay or limestone, or a rock may be in the way of a single root, thus producing decay." Young cotton plants are especially liable to succumb from a disease called "sore-shin"[9] as a result from mechanical injuries.

This disease is wholly different from "seedling rot," which is often called "sore shin." An account of "seedling rot" will not be out of place in this connection.

Throughout the South cotton planters are much annoyed by it. Young cotton plants rot close to the ground; at first the parts turn brown, ultimately shrivel up, and the plant wilts. In some cases "seedling rot" may be due to the difficulty with which the germinating plantlet removes itself from the seed-

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[7] Texas Farm and Ranch, July 15, 1889.

[8] Tenth Census Report, Vol. V, Pt. I, p. 30.

[9] This term is also applied to older plants when injured mechanically. The injured surfaces of such plants frequently contain a gummy exudation. It is not improbable that this helps to repair the wound, as it does not allow the air to come in contact with the wound. Hartig (Zersetzungserscheinungen des Holzes, Berlin, 1878, p. 69) has shown this to be the case with the exudation of liquid resin in Conifers.

coats, and thus becomes more subject to this rot. Planters, however, attribute it to sudden changes in weather, from warm to cold and moist. In some experiments conducted in a green house, at Ames, Iowa, and College Station, Texas, I found one-fifth of the young seedlings dying from "seedling rot," and this, I should say, is not an uncommon experience.[10]

Diseased seedlings have been examined; the mycelium of a fungus was found, but no fruit.[10a]

It hardly seems probable that a large number of plants in different parts of the field should come in contact with a solid stratum of rock, or that the tap-roots of a large number of plants should receive mechanical injuries, and as a result death follow. It is a common practice of nurserymen to place young seedlings on a rock to avoid the formation of a tap-root, and no injurious effects ever come from this practice so far as I know. Investigation has shown that the depth of the underlying strata varies greatly; that cotton dies where the strata are superficial and where they are removed many feet from the surface. Only a few plants have been found that were killed by the fungus which had also received mechanical injuries. I can not insist too strongly on the fact that the lower part of the tap root is often healthy while the thickened upper portion is completely invested with the fungus. In such cases some of the lateral roots also have their normal color.

The insect theory has many followers, but after a thorough examination of a large number of affected plants, I am convinced that insects in no way cause cotton to die. The insects and worms found in the roots of cotton and sweet potatoes live on the decaying substance. Attention should be called to the apple-root plant-louse (*Schizoneura lanigera*, Hausm.), which is common on apple roots in Texas. This will be referred to again in another connection.

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[10]Darwin. (The Power of Movements in Plants, London, 1880, p. 168). Could only make few experiments to test the sensitiveness of the apex of the radicle, as they soon became unhealthy when suspended in the air.

[10a]It has long been known that clover, pepper grass, shepherd's purse, millet, Indian corn, and other seedlings are subject to the attacks of a parasitic fungus (*Pythium De Baryanum*, Hesse), a fungus closely related to potato rot, *Phytopthora infestans*, and the grape vine mildew, *Peronospera viticola*. The Pythium fungus causes the parts near the ground to turn brown. The stem or root shrivels up and the plant soon wilts.

Most of the species of the Pythium are saprophytic, while some are facultative parasites to some extent. De Bary (Comparative Morphology and Biology of the Fungi Mycetozoa and Bacteria, English translation, Garnsey and Balfour, Oxford, 1887, p. 382) says that *Pythium De Baryanum* is not only a parasite attacking living and healthy plants with its germ tubes, but grows equally well on decaying organic substances. It is parasitic on a large number of Monocotyledons and Dicotyledons and the Prothallia of ferns. It does not, however, attack such algæ as *Spirogyra* and *Vaucheria*. The fungus is especially troublesome to members of the mustard family (*Cruciferæ*, also *Amarantus*). It destroys them completely in a very short time. Full grown land plants are not so readily subject to its attacks, but when such plants are placed in water they are readily attacked and destroyed. Another fungus belonging to this group also attacks and destroys seedlings, especially trees; it is *Phytopthora omnivora*, De Bary, and is closely related to the potato rot. This fungus was fully described and studied by Hartig. (Untersuchungen aus dem Forstbotanischen Institut, 1880, pp. 33–57; Lehrbuch der Baumkrankheiten, 1882, p. 42). According to De Bary (Zur Kenntniss der Peronosporen, Bot. Zeitung, 1887, p. 593) and Sorauer (Handbuch der Pflanzenkrankheiten, Second Part, p. 157) it occurs on the seedlings of *Clarkia*, *Gilia capitata*, *Cleome violacea*, etc., on seedling trees of *Picea excelsa*, *Pinus sylvestris*, *Strobus*, *P. Laricio*, *Larix Europœa*, *Acer platanoides*, *Fagus*. This disease manifests itself by the blackening of the roots and rootlets. The Cotyledons have a spotted appearance. Warm and moist weather causes the fungus to grow rapidly, and in a short time the plant succumbs. In seedling beds the disease spreads centrifugally, and reappears when resown with such plants as it attacks. The oospores are probably formed in the soil and tide the fungus over till spring. Sorauer states that soil where beeches had been killed by the fungus, when used four years later, was still capable of infecting plants.

ALKALI THEORY.

This term is not at all understood by many who use it. There is so much misapprehension, especially when applied to "root rot" of cotton, that I will give a short account: Prof. H. H. Harrington[11] says: "Alkali soil, as the term is commonly employed, has reference usually to the saline or alkaline matter present in the soil that exerts an injurious effect on vegetation. These salts may or may not be alkaline in reaction." Dr. E. M. Hilgard[12] says: "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 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; it is there of course that all 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 merges from the ground."

In this connection the following letter from W. C. Larkin, of Athens, Texas, will be of interest: "The affected soil is dark and sandy, and at times is covered with a whitish looking substance, resembling frost at a distance. It tastes brackish, and when scraped together looks grayish or ash colored. It is mostly in the low lands. In a gradual start, cotton will grow on finely to a certain height, and stop as suddenly as if plowed up Sometimes a stalk of cotton remains; it does not grow high, but bunchy, and makes a full crop without any cultivation. Sometimes a weed also comes up and survives; but generally speaking, cotton never germinates in that land. Open the furrow when the cotton seed is planted, ten or fifteen days after planting, and the seed looks much cleaner than when planted, and seems sound, but take hold of one and it is decayed, and is very easily mashed. If we could get cotton up, I believe that it would grow and make cotton without cultivation. Corn will germinate, but dies out before it gets knee high. I believe that these spots, which increase in size every year, could be redeemed by application of some proper substance. They increase more in a wet spring than a dry one. I have tried to reclaim these spots by turning ditches on them, thereby covering them over to a small depth with such soil as a ditch carries—water coming mostly from uncultivated land—but they seemed to grow larger than the land not receiving such deposit. Nothing ever comes up on this land, while on the "dead and mineral lands" everything grows to maturity except cotton. I have spots in my plantation an acre in size, with luxuriant growth all around them, and these spots are as bare as your hand; and the land or soil looks richer in these spots than anywhere else."

According to Dr. Hilgard,[13] of California, cotton is especially to be recommended, as fibrous rooted plants like cereals are especially subject to die from the effects of "alkali." During two years of field observation, I have never seen a member of the grass family to die from the same fungus that destroys cotton.

It is claimed by some that corn, oats, and wheat are affected. Jeff Wellborn[14] says:

"My prospects were very flattering until we had a soaking rain on May 18,

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[11] Texas Farm and Ranch, June 1, 1889.

[12] Tenth Census, Cotton Production, Vol. VI, Pt. III, Special Report California.

[13] L. C. p. 11.

[14] Texas Farm and Ranch, July 15, and November 1, 1889.

when about two-thirds of the corn on one-half of the acre fell over on the ground, rootless. The other third was wilted, but stood up. Mr. J. S. Peters called my attention to a little patch of sorghum, the roots of which seemed to be affected in some way. I made an examination of the roots, but could find no traces of the cotton fungus." From numerous answers received to the postal circular sent out by the Experiment Station, only a few have observed the falling over of corn.

Prof. Burrill has lately shown that a Bacillus[15] is the cause of a wide spread disease in Indian corn. That the disease of Indian corn and cotton should occur on the same ground must not be regarded as proof that the two diseases are the same. The roots of the diseased corn do not show the cotton fungus. The two diseases should be clearly distinguished, and in order not to cause confusion I will give a brief account of the corn disease.[16]

The young plants are dwarfed. It occurs on spots of various sizes, from a few square rods to an acre or more, or it may be widely scattered through the field, affecting a hill or stalk here and there. It becomes yellow and unusually slender, most of it dying. Occasionally a few stalks recover. When affected plants are pulled from the ground the oldest and lowest roots are found to be dead. The bottom portion of the stalk is dead or dying. On the surface brownish corroded spots can be found. These corroded spots contain a semi-transparent, rather firm, gelatinous material. This gelatinous mass is made up of the minute organisms causing the disease.

In Bulletin No. 4 my reasons were given for calling this disease "root rot" or "pourridie." There can be no doubt that the "dying of cotton" and apple trees and the rotting of sweet potatoes is caused by the direct action of a parasitic fungus, and as this term is well established for those diseases, and as it is not likely to lead to confusion, it should be used. In talking about the disease to farmers I have often been asked what a fungus is. In order to make the matter of this report clear, I can do no better than give a brief account of one of these low forms of plant life. Fungi are plants just as much as cotton and wheat. In many cases they are small, and require a powerful microscope to bring out their structure. Scientists have long since established that "rusts," "smuts," "mildews," and "blights" are caused by parasitic fungi. The farmer and gardener have supposed that these diseases are caused by exhaustion of the soil, changes of the weather, or inherent weakness of the plant affected, but these various diseases have appeared under very different conditions of soil and atmosphere.

Fungus is a plant of low organization, having a vegetive as well as a reproductive system. Chlorophyll, the green coloring matter found in leaves and other parts of plants, which enables them to make starch (plant food) out of unorganized material, is absent. The life history of many fungi is quite complex; in some cases stages of the same fungus occur on different host plants as in Grass-rust (*Puccinia Graminis*, Pers.). Two stages are found on oats, wheat, and other members of the Grass family, while the first stage occurs on the Barberry. We can best illustrate the life history of a fungus by taking a common mold (*Mucor*), which is not uncommon on rotting sweet potatoes—possibly the cause of much of the cellar rot of sweet potatoes. At

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[15] Bacillus is a plant of low organization. Many of these micro-organisms are the cause of various diseases, such as tuberculosis, anthrax, pear blight, sorghum blight, etc.

[16] A Bacterial Disease of Indian corn, Bulletin No. 6, 1889, Illinois Agricultural Experiment Station, proceedings Tenth Annual Meeting of the Society for the Promotion of Agricultural Science, 1889, p. 19. Also an account in Original Investigation of Cattle Diseases in Nebraska, 1886–88, by Dr. F. S. Billings, Bull Experiment Station, Nebraska, p. 199; Iowa Homestead, September 20, 1889; Orange Judd Farmer, August 10, 1889.

first a whitish or grayish mass of threads will be found to cover the potato; this is called the *mycelium.* It is the vegetive part of the fungus, and enables it to take nourishment from the substance upon which it lives. A single thread of the *mycelium* is called a *hypha.* If the fungus on the sweet potato is carefully observed, in a short time (from twenty-four to forty-eight hours) erect branches make their appearance. These are called *conidiophores;* at the end of each a spherical body is found, at first whitish, but later blackish. This is the *sporangium*, and contains thousands of small *spores.* These spores correspond to the seeds of higher plants. They are capable of germination, and falling on a suitable substance develope into the same fungus.[17]

Some of the lower forms of plant life, like "pond scums," mosses, and ferns, contain cholorophyll; these are therefore able to make their own food, but fungi must obtain their food either from living organisms, when they are called *parasitic*, or from decaying organic matter, when they are said to be *saprophytic.* The *Mucor* on sweet potato is a *saprophyte*, while rust of wheat, blight of pear trees, and cotton "root rot" are caused by parasitic fungi.

GENERAL CHARACTERS OF THE DISEASE.

The first thing observed is the sudden wilting of a single plant or a number of them like Lucerene and Clover when affected with the Violet-Root fungus (*Rhizoctonia Medicaginis*, D. C.)[18]

The sudden wilting of cotton is usually first noticed in the later part of June or early in July. The time, however, varies with the locality. Planters not infrequently associate the "dying of cotton" with the appearance of flowers and bolls. From the condition of cotton fields early in July, 1888, I was of the opinion that the disease must make its appearance much earlier in the season. I therefore requested Mr. R. D. Blackshear to make some observations for me. He reports that he noticed plants affected as early as the 6th of May. Young plants are certainly often affected. I have seen the fungus on plants six inches high. The sudden wilting of a large number of plants does not, however, appear till about the middle of June and later. The wilting of a single plant here and there in the field might easily be overlooked by the planter, or, if seen, he might suppose them to be killed from some other cause. But when the infection spreads to neighboring plants his attention is called to them. Starting from a single dead stalk in May or June, areas of considerable extent will be found at the close of the season. The "dead patches" have no definite boundary, extending in all directions through the field; occasionally the black streaks and patches contain a few green plants. In riding on a railroad through the belt where the disease is so prevalent, a striking contrast is formed between the black streaks, everywhere in fields, interspersed with green cotton.

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[17] *Mucor* is taken as an illustration because it is so frequently found on rotting sweet potatoes.

[18] The perfect form of this fungus belongs to one of the Pyrenomycetes. In this group of fungi the spores are found in sacs called *asci.* The *asci* are enclosed in capsules known as *perithecia.* The *asci* contain small spores, the *ascospores;* these are usually not formed till winter or the approach of spring, in the dead parts of plants affected. The sterile threads of *Rhizoctonia violacea*, Tul., or *R. Medicaginis*, D. C., have not been found in this country, although the Snow mold (*Lanosa nivales*, Fr.) which Fuckel considered a stage of the perfect form of *Amphisphaeria zerbina*, De Ntrs. (*Byssothecium circinans*, Fuckel, Bot. Zeit., 1861, p. 250, Symbolæ Mycol., 1870, p. 142; *Hendersonia circinans*, Sacc., Sylloge Fung., Vol. III, p. 431. Saccardo places it with *Leptosphaeria circinans* (Fuckel), Sacc. Syll. Fung. Vol. II, p. 88) has been found at River Falls, Wisconsin, by Professor King. (Trelease, The Fungi of Forage Plants, in Beal's Grasses of North America, Vol. I, p. 426.)

The suddenness with which plants die is governed somewhat by the conditions of the atmosphere and soil. Thus during the dry weather in August, 1888, few plants were dying, and planters frequently said that dry weather did a great deal to check the disease. In the latter part of August rains set in, and during the intervals of hot sunshine a large number of plants were again wilting. In June and July of 1889 it was again found that more plants were affected after a rainy day followed by warm sunshine, than during several days of dry weather.

Healthy plants are frequently found close to diseased ones, often till late in the season. It does not follow that green and apparently healthy plants are not diseased, as I have repeatedly observed. The following will serve to illustrate. Eight plants were found growing in a bunch; two of these had wilted, and in each case the tap-root was covered with the mycelium of the fungus. In two cases the tap-root contained an abundance of the fungus, though these plants had not wilted, but probably would have succumbed in a few days. In two other specimens a small amount of the fungus was found on the tap-root, while only a single one was apparently exempt.

If the roots of a dead cotton stalk or those which are wilting are examined, brown threads of a fungus, *Ozonium auniecomum*, Lk., are found to closely surround the tap-root and some of the lateral roots. Every plant dying from the disease always contains this fungus. In numerous places on the tap-root and lateral roots small wart-like bodies are found (see Plate I, Fig. 2, B, *p*); these frequently occupy the lenticels on the roots. If apparently healthy plants are taken up in close proximity to dead and wilting ones, a whitish mold-like fungus[19] may be seen speading over the tap-root. The same thing may be seen in such cases where the tap-root is covered with brown threads, while the lower end of the tap-root and small lateral roots have their normal

[19] According to the investigations of Frank (Ueber die auf Wurzelsymbiose beruhende ernæhrung gewisser Bæume durch unterirdischer Pilze; Berichte d. deutschen Bot. Gesellschaft, 1885, Vol. III, Heft 4, Abst. Sorauer, Just Bot. Jahrh. 1885, 2, p. 513; Ueber die physiologishe Bedeutung der Mycorhiza Formen, Ber. d. Bot. Gesell., VI, p. 395-409, pl. XIX; abstract Hedwigia, Vol. XXVII, 1888, p. 28; Jour. Royal Microscopical Soc., 1888, Pt. I, p. 268; Kamienski Die Vegetations organe der Monotropa hypopitys. L. Bot. Zeitung, 1881, p. 457; Abst. Just Bot. Jahrh. 1881, 2, p. 717; Ueber Symbiotischer Vereinungen von Pilzmycelium mit den Wurzeln hœherer Pflanzen; Arbeiten der St. Petersburger Naturforscher Gesellschaft, XVII, 1886, p. 34-36; Abst. Soc. Bot. de France 1888, p. 42; Sorauer, Just Bot. Jahresbericht, 1885, 2, p. 513; Rothert, Bot. Centralblatt, Vol. XXX, 1887, p. 2), and others. Some plants, like the oaks, hazelnuts and chestnuts, are enabled to take up the mineral elements of the soil by means of a white mold-like fungus which closely invests the roots, often penetrating the epidermal cells. This fungus has been called *Mycorhiza.* If the views of Frank are correct, then the white mold-like fungus covering the roots of many trees and shrubbery plants cannot be considered a diseased condition. It is only when death or a diminished vitality results from the fungus on the roots that it can be looked upon as a parasite. In this connection O. Penzig's (Die Krankheit der Edelkastanien und B. Frank's *Mycorhiza*, Ber. d. Bot. Gesell., 1885, p. 513), Kamienski (Symbiotischer Vereinungen, etc.) and C. Freih. V. Tubeuf's (Mycorhiza on Pinus cembra, Beitræge zur Kenntniss der Baumkrankheiten, Berlin, 1888, 61 pp., 5 plates, Abst. Hedwigi XXVII, p. 207), should be consulted. Tubeuf does not believe that the fungus on the roots of *Pinus cembra* is a case of symbiosis, and Kamienski holds that symbiosis cannot be applied to all the *Mycorhiza* forms described by Frank; that in case of *Carpinus Betulus* and *Pinus Sylvestris* the mycelium of the fungus causes hypertrophy of the tissues. Dr. Farlow (Vegetable Parasites and Evolution, Vice-Presidential Addr. A. A. A. S., New York meeting, 1887, Bot. Gazette, Vol. XII, p. 173), says: "The word 'symbiosis' was originally applied to all cases where different organisms were associated together in a community, and in this sense included the true parasites· The application has gradually been modified until at the present day symbiosis is generally understood to mean the association of plants with plants, or plants with animals, in such a way that the relation between them is one of mutual benefit, or in which there is at least no injurious action of one organism on the other."

color. The white threads gradually assume a darker color, becoming either dirty white or brown. In cross sections of a diseased root, the characteristic branched threads of *Ozonium* are found on the surface, while the vessels and meduallary rays also contain them.

Through the action of the fungus a fermentation is set up. This fermentation causes the tissues to shrivel up, thus leaving depressions. The borders of these depressions show at first a red discoloration; this ultimately becomes brown. The fungus threads are often removed some distance from the part which is taking on the red discoloration. This is not uncommon. Hartig, Sachs,[20] and others have shown that hyphæ exert a decomposing influence on the tissues of plants far beyond their immediate neighborhood, extracting substances which serve to nourish the fungus.

Near the surface of the soil the cotton stalk usually shows an enlargement (see Plate I, Fig. A, *e*), large when fungus and cotton are growing rapidly. On poor soil and during dry weather it is not so perceptible. It is caused through the shrinkage of the tissue below the point of attack, and the storage of elaborated material in the enlargement. The enlargement contains a large deposit of yellow oily matter contained in glands of a spherical or ovoid shape. New rootlets are thrown out at the enlargement, as shown in the figure at *r*, and under favorable conditions the plant is thus capable of maintaining itself.

In some cases the part of the stem containing the enlargement becomes diseased, especially after rains have washed soil upon the stem. The immediate cause of death is due to the small amount of water the rootlets are absorbing, while the amount of water transpired is far in excess of what they are capable of taking up. Root absorption is necessarily reduced as the supply of elaborated material is cut off, owing to the dead tissue of the main part of the tap root, and thus the elaborated material cannot reach the developing rootlets, and the lateral roots from the enlargement are often not sufficiently developed to perform the entire work of absorption, especially so when the surface soil is hard and compact.

WHAT PLANTS ARE AFFECTED BY THE COTTON FUNGUS.

Like *Dematophora necatrix*[21] (the fungus causing "pourridie" of the vine in Europe), *Agaricus Mellens,*[22] *Rhizoctonia Medicaginis,*[23] and other fungi affect-

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[20]Hartig Wichtige Krankheiten der Waldbæume, Berlin, 1874; Zersetzungserscheinungen des Holzes, Berlin, 1878.

Sachs Vorlesungen ueber Pflanzen-Physiologie, Eng. translation, H. Marshall Ward, Oxford, 1887, p. 388.

[21]Hartig Untersuchungen aus dem forstbotanischen Institut zu Munnchen, iii, Heft, 1883, pp. 95–140, two lithographic plates and nine wood cuts, Der Wurzelpilz des Weinstockes, (Dematophora necatrix R., Htg.), Berlin, 1883; O. Penzig et T. Poggi Il. malebianco delle vitie deglí allberida fruttaiee, 47 pp.; Pierre Viala, Les Maladies de la Vigne, Montpellier and Paris, 1887.

[22]Hartig Lehrbuch der Baumkrankheiten, Berlin, 1882, p. 92, etc.

[23]O. Penzig Funghi Agrumicoli: Contribuzione allo studio dei funghi parassiti degli agrumi, Padova, 1882, p. 124, with 136 colored plates. Text appeared in Michelia, Vol. VIII, plates in Saccardo Iconographie Fungi italia, Fasc 15 and 16. Abst. Penzig Just Bot. Jahresbericht, 1882, p. 215, Bot. Centralblatt, Vol. XIV, p. 80), says: *Rhizoctonia Medicaginis,* D. C. (synonomy *R. violacea, R. Crocorum*), is widely distributed on lemon and orange roots in Italy. According to E. Rostrup, (Sur quelques deformations des Phanérogames causées par les Champignons parasites, Botanisk Tidsskrift, Copenhagen, Vol. XIV, 1885. French resumé, p. 21, Abst., Sorauer Just Bot. Jahresbericht, 1885, p. 515. See also his paper Undersogelser over Svampeslaegten Rhizoctonia, separate, from Oversigt over det K. Danske Videns Srabernes Selskabs Forhandlinger, 2 plates with French resumé, Copenhagen, 1886, Abstract Jœrgensen, Bot. Centralblatt, Vol. XXX, p. 98), occurs on *Trifolium pratense, T. hy-*

ing roots, it also occurs on widely different hosts. In Texas thousands of bushels of sweet potatoes are destroyed by *Ozonium auricomum*. It is not the only fungus, however, which causes a rotting of the roots. In New Jersey, where sweet potatoes are often affected with a rot, Mr. J. B. Ellis[24] did not find a fungus. Dr. Halsted writes me that he has seen considerable of a sweet potato rot in New Jersey upon which he has found *Mucor* (black mold), and that the disease can be communicated to Irish potatoes, turnips, and beets. Prof. Trelease has called my attention to a sweet potato disease in the peninsular parts of Maryland and Virginia, to which Dr. O. Lugger has given some attention. He describes the disease as follows: "In every case the original and central plant showed the disease first; this was indicated by turning black and then dying; when the central root was pulled up, it was also black and decayed. The runners would keep on growing, but produced no tubers, or only very small ones."

Another sweet potato disease occurs in this country, *Rhizoctonia Batatas*, Fr. Through the kindness of Dr. Farlaow I have been enabled to examine a specimen from the collection of Schweinitz.[25] Whether it is the cause of the "Peninsular" sweet potato disease of Maryland and Virginia I am unable to say. It certainly is entirely distinct from the Texas disease. W. G. Smith[26] has found the "seedling rot" fungus, *Pythium De Baryanum*, on New Zealand sweet potatoes. (*Ipomœa chrysorhiza.*)

In the Texas disease the fungus begins to work on the surface, but in the advanced stages the whole root is found to be covered with the brown threads of the fungus. In some specimens sent to me, and considered sound, I found a number of depressions, in the center of each a small whitish protuberance (see Plate I, Fig. 1, *d*) composed of a mass of fungus threads similar to those on the roots of cotton. The cells adjoining the depression were soft and undergoing decomposition. The rot may begin at the end and work gradually over the entire root. The vines grow on vigorously and show no external symptoms, but at the time of maturity nothing else but the decayed remains of potatoes can be seen, while on the borders of the patch diseased potatoes of all sizes showing different stages of the fungus can be found.

After the *Ozonium* has attacked the root, a speedy decomposition of the tissues takes place, due largely, however, to saprophytic fungi, such as *Mucor*, *Verticillium*, and various bacteria. This will be referred to again in another connection.

THE FUNGUS ON FOREST AND APPLE TREES.

Texas farmers and horticulturists have long been familiar with a disease that destroys forest and fruit trees in a manner similar to that of cotton, and they have believed that the agent which destroys the one also destroys the other. Whenever cotton dies from "root-rot" apple and forest trees are likely also to die. In nurseries it is confined to spots, spreading centrifugally, killing everything but the genus *Prunus* (such as plum and peach.) I have seen diseased specimens of apple and forest trees from Burnet, Collin, Ellis, Dallas, and Grayson counties. In Dallas the following trees were affec-

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bridum, *T. repens*, *Medicago sativa*, *M. Lupulina*, *Rumex crispus*, *Geranium pusillum*, *Sambucus Ebulus*, *Coronilla varia*, *Ononis spinosa*. In Bull. 4, Texas Agrl. Experiment Station, other references to species are given.

[24] New Jersey State Agricultural Experiment Station, Report 1881, p. 65.

[25] Synopsis Fungorum * * * Am. Bor., p. 264, No. 2396; Fries, Elencho Fungorum, II, p. 45; Sorauer, l. c. p. 359.

[26] Gardo Chronicle, 1884, II, p. 555, p. 447.

ted: Elm (*Ulmus Americana*), Basswood (*Tilia Americana*), White Ash (*Fraxiuns Americana*), Apple trees (*Pyrus Malus*), Russian Mulberry (*Morus alba*), China tree (*Melia Azedarach*); some Conifers (*Thuja*) were dead, but as they were killed the previous summer it was hard to say that *Ozonium* was the cause. Near McKinney and in Sherman the following additional trees were found: Japan Persimmon (*Diospyros Kaki*) grafted on the native Persimmon (*D. Virginiana*), Silver Maple (*Acer dasycarpum*), Paper Mulberry (*Broussonetia papyrifera*).

Of this list the China and Paper Mulberry trees suffer most. In August, 1888, the roots of a number of China trees were found covered with *Ozonium*. In July, 1889, the place was revisited; the old trees were dead, and the infection had spread to neighboring young Paper Mulberry trees.

In many cases old and dying trees send up suckers; thus at Anna a number of old Paper Mulberry trees were almost dead; hundreds of suckers from six inches to two feet high covered an area of several rods; among them also a large number of *Sida spinosa* was growing. The suckers and the weeds were wilting in large numbers, while many were dead. In every case the roots were covered with the fungus.

The Pear (*Pyrus communis*) is said also to be affected. Specimens sent to me from Mr. Ramsey, of Burnet County, had plenty of the *Ozonium*, but the trees had evidently been dead for some time. In the pear orchard of Mr. R. D. Blackshear, the leaves of trees covering an area of several acres became yellow and soon died. The pear trees alongside of this patch were perfect, showing no signs whatever of yellow leaves. The roots of the trees with yellow leaves were examined carefully, but no fungus was found on the roots, except in advanced stages, when numerous threads of the *Ozonium* were present, but I think in those cases the fungus was simply a saprophyte. It should be stated that seven-eighths of the cotton in this patch was dying from "root-rot." Cotton was also dying, though not so bad, where the pear trees had their normal appearance. This case has been given, as it has been stated that the cause which killed cotton also produced the "yellows" of the pear trees. A white rock comes close to the surface, but I can not say whether it is in any way responsible for the disease or not. The area was sharply defined. I am unable to account for this disease.[27]

The leaves of the young apple trees affected with "root-rot" suddenly wilt, become black, and in a short time perish. In older trees death is more gradual. They have a sickly appearance one or more years previous to death. It bears a heavy crop of fruit and then dies. If young seedlings are taken up in close proximity to dead trees the tap-root will be found to contain the same white fungus threads that diseased cotton roots show in its early stage. In other cases the leaves are still green, no external symptoms are noticed, but the tap-root is closed invested with the brown threads of *Ozonium*. At McKinney eight affected trees were found in a row close to some which had been dead some time. The fungus had completely surrounded the tap-root, as well as some of the lateral roots, but in addition small knot-like bodies

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[27] A disease called Chlorosis causes a blanching of the plants from lack of iron, but it does not seem that iron is lacking in the soil at Navasota. In Icteriosis, also called chlorosis by some, the leaves are blanched, and by some supposed to be due to a want of potash. In France the Herbemont grape is especially subject to this disease. (G. Foex, Des causes de la chlorose chez l' Herbemont, Ann. Ecol. Agrl., Montpellier, 1886; Viala Les Maladies de la Vigne, p. 430, Sorauer, l. c., Vol. II, p. 188.) In this case there seems to be a non-adaptation, but in some of the manifestations of the disease the cause does not seem to be clearly understood. One correspondent writes that some of his pear trees showed this disease, and they were restored by the use of iron.

were found on all the trees. I had not noticed these in the orchards at Ennis nor Dallas. Later, however, I observed these knotty bodies on apple trees at Anna and Howe, and I am told that they are quite common in many parts of Texas. This insect, the Apple-root Plant-louse (*Sehizonleura lanigera*, Hausm.), kindly determined for me by Prof. Osborn, was doing much damage at the above places. Many orchards presented a sad spectacle, and the trouble was pronounced "alkali." In order that the two diseases should not be confused, I will give a brief description of the insect which causes these deformities on the roots. The insect[28] is easily recognized by the bluish-white cottony matter with which its body is covered, and the knotty roots it forms. See Plate I, Fig. 5. It seriously diminishes the normal supply of nourishment, and when so numerous as I have seen them at Anna, Howe, and McKinney, certainly prepare the way for fungi, and other insects to get a foot hold, and thus soon destroy the tree.[29]

We must clearly distinguish between the two diseases. In the insect trouble, death is much slower, while in "root-rot" of apple trees, especially in younger trees, death is rapid. The *Ozonium* and *Schizoneura* frequently occur on the same root, but often quite independent of each other, so that the *Ozonium* does not attack the root, because the way has been prepared for it by the insect.

The fungus on apple roots seems to have been known for a long time. Dr. Riley writes me concerning it: "I have long been familar with the brown fungus which you mention, and which years ago was very common in Southern Illinois." There seems to be another disease affecting apple and pear roots in Southern Illinois, but it has no likeness to the Texas disease. Mr. F. S. Earle[30] writes me: "While I have no proof that amounts to a demonstration that *Polyporus versicolor* causes rot of apple, pear, and cherry trees, still I have no doubt it is a fact, and that it also injures many other trees and shrubs. I do not remember noticing the brown mycelium you mention. In Southern Illinois the 'root rot' mycelium was usually white." *Rhizoctonia Mali*, D. C.,[31] a description of which I have not seen, is said to occur on the roots of young apple trees in Europe. I can not say whether it is identical with the *Ozonium* on apple roots or not.

WEEDS AFFECTED.

If fungicides will not destroy the pest, then a more judicious method of cultivation must be resorted to. It will be of little use to rotate, if weeds which harbor the fungus are allowed to grow in the field. Of the many weeds growing in cotton and corn fields in Texas, the common Sida (*Sida Spinosa*) (Plate I, Figs 1 and 2) is more subject to this disease than any other. It belongsto the same family that Cotton, Okra and Hollyhock do. In well worked

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[28]C. V. Riley Apple-root Plant-louse, First Annual Rep. on Noxious, Beneficial, and other Insects of Missouri, 1869, p. 118, and numerous other papers.

[29]The following remedy has proved beneficial for destroying the Apple-root Plant-louse: Use scalding hot water around the roots of the trees. If the trees remain in the soil the roots should be laid bare, and nearly boiling water can be used. If trees are taken up for transplanting, the water should have a temperature of not over 150 degrees Fahrenheit. Mulching the trees previous to the use of hot water will bring the lice close to the surface. Bisulphide of Carbon and Kerosene are excellent remedies when placed in soil around the diseased tree.

[30]Pear Diseases caused by Fungi; from Transactions of Ill. Hort. So., vol. XX, 1886, p. 168.

[31]Sorauer Pflanzen Krankheiten, Vol. II, p. 359; De Candolle in Mém. Mus., 1815, p. 209; Freis. Syst. Myc. ii, p. 266.

fields the weed is isolated and scattered. If careful search is made, plants here and there will be found to be affected with "root-rot," showing the same symptoms that cotton does. Thus, in a neglected orchard, I saw hundreds of specimens of this weed dying close to a number of Paper Mulberry trees. I have occasionally seen one of the Ragweeds (*Ambrosia psilostchya*), Cocklebur (*Xanthium Canadense*), and a few other undetermined composites dying, but in all cases I found that the plants had sustained some injury. The fungus, no doubt, caused death, but it was easier for it to attack such plants because of the injury.[32]

The fact that *Ozonium* attacks such plants as *Ambrosia* and *Xanthium* when they are injured may seem to some not sufficient reason for regarding it as a parasite. The *Sclerotinia Sclerotiorum* on the Common Bean does not even attack all varieties of *Phaseolus vulgaris*, nor is the related species, *Phaseolus multiflorus*, seldom attacked. *Agaricus melleus* attacks various conifers as a true parasite, but it is seldom found on deciduous trees, except under some conditions.

I have stated elsewhere that various species of *Prunus*, such as peach and plum, do not show the *Ozonium* disease, at least I have not been able to find any specimens, though they may die from other "root rot" diseases.[33]

BOTANICAL CHARACTERS.

Ozonium auricomum were described by Link in his Observationes Mycologicae.[34] It is widely distributed in Europe as well as America, occurring

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[32]Thus very many fungi do not attack sound and healthy parts of plants, but when, for instance, the surface of an apple is injured, molds (*Mucor*, *Trichothecium*, *Penicillium*, etc.) of various kinds make their way into the tissues, causing a rot. The Scelerotium disease of the Common Bean is of interest in this connection. According to De Bary (Comparative Morphology and Biology of the Fungi Mycetozoa and Bacteria, English translation, Garnsey and Balfour, Oxford, 1887, p. 380; also Ueber Einige Sclerotinien und Sclerotienkrankheiten, Bot. Zeitung, 1886, pp. 377, 393, 409, 433, 449, 465; Abstract Zimmermann, Bot. Centralblatt, Vol. XXIX, pp. 97–107), when spores which have germinated in pure water are used to infect young seedlings of the Garden Bean (*Phaseolus Vulgaris*) the result will be a negative one, as they will not take the disease, but if the spores are made to germinate in a nutrient solution, the germinating tube becomes strong enough to penetrate the epidermis, soon produces a vigorous mycelium, and destroys the plant.

[33]Hartig, Lehrbuch, p. 92, Der Wurzelpilz des Weinstockes, etc., p. 3; Viala Les Maladies de la Vigne, p. 357, Earle l. c., p. 168, etc., etc.

[34]I, p. 9; Id. Linne, Spec. plant, cura Willdenow VI, I, p. 138; Fuckel Symbolae mycologicae, p. 403; Saccardo Mycologia Veneta, p. 204; Sylloge Fungorum, Vol. VI, p. 345; Michelia, vol. II, pp. 134, 490; Rabenhorst, Deutschl. Kryptogamen Flora, p. 60, No. 581; Winter Die Pilze, Vol. I, p. 405; Wallroth, Flora Germanica, Crypt. II, p. 156; Cattaneo Estratto dai Rendiconti del R. Instituto Lombardy, Ser. v, Vol. XII, fasc. VII, 1879; Abs. Schrœter, Just Bot. Jahresbericht, 1879, I, p. 551; O. Penzig Nuovo Giorn. Bot. Ital. XII, pp. 132–143 two lith. plates; Abst. Penzig Just Bot. Jahresbericht, 1881, I, pp. 244, 248; Holuby Oesterreichische, Bot. Zeitung, 1874, pp. 311–313; Abst. J. Schrœter, Just Bot. Jahresbericht, 1874, p. 204; Felix von Thümen Die Pilze und Pocken auf Wein und Obst, Vienna, 1878, p. 165.

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SYNONOMY.

Ozonium fulvum, Persoon Mycol. Europ. I. p., 87; *Byssus fulva* Humb. Fl. Freiberg, p. 62, No. 109; *B. aurantiaca*, De Candolle, Fl. Franc. ii. p. 68; Lamarck Encycl. I, p. 524; *B. aurea arborea*, Weiss, Fl. Goett, p. 14; *B. barbata*, Engl. Bot. Fig. 701; *B. sericea*, Scopoli, Dis. I, p. 90, Pl. II, in damp places on the decaying bark and wood of various trees. What ordinarily passes for *Ozonium auricomum*, Lk., is a saprophyte. The specimen of *Ozonium auricomum* distributed in Ellis' North American Fungi, and Fungi Gallici and some herbarium specimens which I have examined, are morphologically distinct from the Texas material.

In Italy *Ozonium auricomum* is not uncommon on orange roots,[35] but so so far as known it has not been found on the roots of orange and lemon trees in this country. It has long been known that *Ozonium*, *Rhizoctonia*, *Rhizomorpha*, etc., are only sterile stages of some fruiting fungus. Thus *Rhizomorpha fragilis* and *R. subcortalis* have been placed with *Agaricus melleus*, *Rhizoctonia Medicaginis* with *Trematosphœria circinans*, *Rhizoctonia Querci* with *Rosellina Quercina.*

Opinions differ in regard to the perfect form of *Ozonium.* Schroeter[36] believes that it develops into *Coprinus radians*—one of the toad stools. Penzig,[37] however, states that it develops into a species of *Coprinus*, which he has called *C. intermedius.* Mr. J. B Ellis writes me that Langlois has found in Louisiana what appears to be this species. Winter[38] and Saccardo[39] place it with *Trametes odorata*, Wulff. Holuby[40] with *Agaricus deliquescens*, Bull. No doubt the ordinary damp wood form of *Ozonium* is probably connected with some *Hymenomycete*, but I am inclined to believe that the Texas fungus is connected with some *Pyrenomycete.* It should be stated here that yellow strands much thicker than *Ozonium* are of common occurrence on dead stalks of cotton, and sometimes even found on plants that are wilting and those that have received mechanical injuries. This fungus is probably connected with one of the *Polyporei* (fleshy fungi). In several cases these strands were seen to develop into a *Polyporus* or a *Trametes*, but not enough was found to enable me to determine the fungus. These yellow strands are exceedingly common in the soil not only where cotton is dying, but also in places where the disease does not occur. I think little harm is done by this fungus.

In 1888, and again the past season, diseased roots were placed in a chamber kept moderately moist, but in no case did a *Hymenomycetous* fungus make its appearance. *Verticillium*, *Trichothecium*, *Penicillium*, and other saprophytic fungi frequently occurred but not a single *Hymenomycete.*

In sweet potatoes which were undergoing decay, the interior, and parts as

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Fig. 2; *Himantia fulva*, Sprengel Syst. IV, p. 559; *Himantia strigosa*, Persoon, Mycol. Europ. I, p. 704; *Rhizomorpha capillaris*, Roth., Cat. I, p. 234; *Racodium strigosum*, Persoon Mycol. Europ. I, p. 69; *Ceratonema capillare*, Roth., Catalecta II, p. 251; *Amphiconium Strigosum*, N. Syst., p. 344; *Dematium strigosum*, Persoon, Despositio fung., p. 75; Schweinitz Syn. Car. No. 1328, p. 128 [102]; *Mesenterica lutea*, Alb. et Schw., Conspectus, p. 374, No. 1126.

EXICCATI.

Roumeguere, Fungi Gallici No. 899; Ellis, North American Fungi No. 832 (distributed as *O. parietinum*), but Ellis writes that it is the same as Fung. Gallici No. 899. Mr. Ellis has been kind enough to send me a specimen of Fung. Gall., 899, and I should certainly say the two specimens are identical; Seymour and Earle Economic Fungi No. 2.

[35] Michelia, Vol. II, p. 490: "Hyphis repentibus, ramosis, irregulariter intertextis, in fasciculos plus minusve crassos coalitis, parce septatis, rigidis luteis v. aurantiacis, junioribus tenuissimis albis. Hab. in truncis vetustis radicibusque Citrorum, frequens."

A. Cattaneo, I, Miceti degli agrumi (Estratto dei Rendiconti, etc., l. c).

[36] Kryptogamen-Flora von Schlesien, Breslau, 1889, p. 519.

[37] Sui rapporti genetici tra *Ozonium* et *Coprinus*, Nuovo Giorn. Bot. Ital. XII, p. 132-43.

[38] Die Pilze, Vol. I, p. 405.

[39] Saccordo Sylloge Fung., Vol. VI, p. 345.

[40] Zur Kryptogamen Flora von Ns. Podhrad Oest. Bot. Zeitung, 1874.

far as the disease had spread, contained the mycelium of a fungus. Morphologically this fungus is the same as the *Ozonium* found on the surface; the characteristic branches as shown in Plate III, Fig. 1, at *b*, are not present, owing to the development of the fungus in the interior of the tissues. Like the cells of the *Ozonium* strands on the surface, they are more or less rounded out at the extremity. In numerous places black perithecia-like bodies (Plate III, Fig. 3 l) occur. It seemed that by cultivating the fungus in a nutritive medium made from sweet potato that the life history of the fungus might possibly be determined. A small portion of the sweet potato containing the black bodies was placed in a test tube containing gelatine. It was well mixed with the gelatine and carried on to the third dilution. The gelatine in each of the tubes was then poured out on plates and carefully observed each day. I had much disappointment, as *Mucors*, *Penicillium glaucum*, *Asperigillus glaucus*, and other *Aspergilli*, *Cladosporium herbarum*, *Bacillus prodigiosus* and other *Bacteria* grew so rapidly that it was difficult to get pure cultures. Then the tip of a few threads was brushed with the point of a sterilized platinum needle in order to get a single spore, or at most only a few spores, from a single thread. In this way, after a short time, a pure culture of some fungus was obtained. It was transferred from the gelatine over to sweet potato agar agar and boiled sweet potato. The white fluffy fungus produced an abundance of spores. The cultures were then placed away, and in May, 1889, the cotton plug contained a large number of perithecia (Plate III, Fig. 4) filled with small spores. These spores germinate readily, and develop into the white fluffy form of the fungus. At the same time when the black perithecia-like bodies were being isolated from the rotten sweet potato, a few of the brown *Ozonium* threads on the surface of a diseased potato were carefully washed with water containing a small amount of acetic acid to prevent the appearance of bacteria. Then a few of the washed threads were placed in a hanging drop culture of sweet potato gelatine. Soon an abundance of threads and spores like those from the black perithecia-like bodies of the sweet potato were produced. In one instance it seemed as though these came from the brown threads, yet it was difficult to determine positively. The hanging drop culture contained but few impurities, so that a pure culture of the fungus was soon obtained on sweet potato gelatine, afterward transferred to agar. Detached spores of similar appearance are frequently found among the brown threads of the *Ozonium*, and of course a single spore which I may not have detected might have been in the hanging drop culture, germinated and developed into the white fluffy fungus, so that perhaps no special significance can be attached to the result.

It was necessary now to determine whether the fungus from the black bodies in the sweet potato could induce decay. In order to test this, the surface of some sound sweet potatoes were thoroughly washed with a disinfecting solution (corrosive sublimate), then sterilized knives were taken and pieces cut out small enough to readily pass into a five inch test tube also previously sterilized. Two series were started; in one some of the conidia from the black bodies were placed, the other was kept as a check. The infected blocks were soon covered with the white threads of the fungus, which caused the tissues to turn black. The checks remained free till the first of June, when they were destroyed. In September the material from one of the infected tubes was taken out. The cotton plug was found to contain a large number of perithecia filled with small spores, while the piece of sound sweet potato placed in the tube was thoroughly rotten.

I do not think the proof is conclusive that the above fungus is connected with *Ozonium*, for the brown threads have not appeared in any of my cultures, but according to Meyer[41] and Gasperini[42] parasitic fungi, when grown as saprophytes in a nutritive medium do not always show the different forms.

It will make little difference from a practical standpoint whether the white fluffy fungus from the sweet potato is connected with the *Ozonium* or not. It should be guarded against, however, as there is no doubt that it induces decay in young cotton roots as well as sound sweet potatoes.

OTHER FUNGI ON THE ROOTS OF COTTON AND SWEET POTATO.

In "root rot" diseases it is no easy matter to decide what particular fungus is the real cause of rot. Speerschneider,[43] De Bary,[44] and numerous other investigators since have shown beyond any doubt that the Potato Rot fungus (*Phytopthora infestans,* De Bary) attacks both the leaves and tubers of the potato, that the mycelium works its way down through the stem, till the tuber is reached, where it causes a dry rot. Many other fungi have been found on rotting potatoes, and according to Reinke and Berthold[45] wet rot is caused by bacteria and various fungi which come in after the potato has been attacked by *Phytopthora.* The complete destruction of the sweet potato is also caused by other fungi, the *Ozonium* only preparing the way. Thus several species of *Mucors*, *Bacillus prodigiosus*, *Verticillum* (see Plate V, Fig. 3), a whitish saprophytic fungus common on decaying substances, *Trichothecium roseum*, *Aspergillus glaucus*, and *Asp. Sp.*, *Penicillium glaucum*, *Cladosporium herbarum*, and others; all common fungi found every where on decaying organic matter, or in some cases restricted to a narrow parasticism. So that on examination of rotten sweet potatoes and the stalks of cotton which have long been dead, it would be useless to endeavor to determine the cause of death. It is only by experimental method or in studying the successive stages of the fungus on the living root that conclusions can de drawn.

When roots just killed with the *Ozonium* are placed in a moist chamber, *Trichothecium*, *Verticillium*, and *Cladosporium* are most common; but when cultures are made in a nutritive medium species of *Mucors* and liquefying bacteria are usually more common than anything else. Some of these probably came from the air, but when they appear in the majority of cultures with as little exposure to the air as possible, it is not unreasonable to suppose that some of these organisms came from the roots and that they play an important part in the complete destruction of the roots.

THE CHARACTER OF THE LINT OF DISEASED COTTON.

Cotton pickers know that when cotton is affected with "root-rot" bolls not more than half mature, and those nearly mature will open, and contain some cotton. Often it is not touched, but when in fairly good condition it is picked, and thrown in with the other cotton. Such a boll is shown at Plate IV, Fig. A. On the same plate at B is a boll from a good stalk not affected, grown on the same soil. A microscopic examination of the lint taken from the different

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[41] Untersuchungen über di Entwickelung einiger parasitischer Pilze bei saprophytischer Ernæhrung, Landw. Jahrbücher, Vol. XVII, pp. 915–945. Abst. Sachsse Biedermann's Centralblatt, für Agrl. Chem. 1889, p. 200.

[42] La biologia e piú specialmente il polimorfismo di varie specie d' Ifomiceti (Polymorphism of the Hyphomycetes) Atti Soc., Tosc. Sci. Nat., VI, 1887, pp. 20–26; Abst. Jour. Roy. Mic. Soc., 1888, Pt. I, p. 468; Abst. Solla Just Bot. Jahresberict, 1887, p. 544.

[43] Bot. Zeitung, 1857, No. 8.

[44] Die gegenwærtige herrschende Kartoffelkrankheit, Leipzig, 1861.

[45] Die Zersetzung der Kartoffel durch Pilze. Untersuchungen aus dem Botanischen Laboratorium der Universitæt Gœttingen, Heft I, 9 Lith. plates, p. 100, Berlin, 1879.

bolls shows a great difference. In the cotton from a diseased stalk, the fibers are very much wider and larger; it has little spirality (Plate V, Fig. 1) and is very uneven. In the good cotton, the fibers are much narrower and of uniform width, the spirality is much more pronounced.[46] (Plate V, Fig. 2.)

THE SEED OF DISEASED COTTON.

Some planters claim that "root rot" results from poor seed. To determine this point, I took one hundred and fifty seeds indiscriminately from a package of seeds from diseased stalks gathered in 1888. I then selected seventy-five seeds each from two samples of Jeff. Wellborn and Hopkins' Improved, gathered in 1887. I then set out alternate rows each of Wellborn, Diseased, and Hopkins' Improved, Diseased, etc. The seeds were planted on August 11th in the propagating house of the Iowa Experiment Station.[46a] On August 11th some of it had germinated, and on August 29th when the experiment ceased. Eighty per cent of the diseased germinated and doing as well as either of the others. Fifty per cent of the Hopkins germinated, while only forty per cent of the Wellborn germinated.[47] In no case did the *Ozonium* appear, though many of the young plants died of "seedling rot." What the quality of the lint would be, and the susceptibility of the plants taking the disease, when seed is used from plants which have been killed by the *Ozonium*, I can not say, though it is not improbable that the lint will be of a much poorer quality.

TREATMENT.

First of all we should recognize that the disease is an infectious one. It makes its appearance in cotton fields, where sweet potatoes, apple, and forest trees have been killed. That infected soil taken to places where the disease has not been before is capable of infecting plants when grown in such places. Strands of the *Ozonium* can be taken and cotton infected with it. A. W. Kerr, of Sherman, showed me a Red Mulberry tree which was killed by "root-rot" in 1887. The following year a small patch of ground where the Mulberry tree stood was planted in sweet potatoes, and where the Mulberry tree stood every potato was rotten; from this point it spread centrifugally, till it became less and less. Dr. Fears, of Waxahachie,[48] took soil from an affected area to an unaffected. The disease then made its appearance in the unaffected places, causing plants to die of "root-rot."

Hope had been entertained by many that some fungicide might prove beneficial in preventing the disease. From the experiments made Mr. R. D. Blackshear under the direction of Prof. F. A. Gulley, the treated as well as the untreated plots showed the disease badly. The experimental ground was one which had been in cotton many years, and in 1888 seven-eighths of it died.

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[46] Thomas Pray (a lecture delivered before the Franklin Institute, Friday, December, 2 1888, Journal of the Franklin Institute Vol. CXXVIII, p. 241) gives an interesting account of different cotton fibers and the use of the microscope in the purchase of cotton. He says: "Just imagine a man going into a darkened room to buy silks, and depending upon 'feeling' with his fingers; he might tell that the fabric was silk, but what could he tell about color or texture? So in buying cotton what could a man tell about a cotton fiber which is all the way from $\frac{1}{900}$ of an inch in diameter for the coarsest upland, and $\frac{1}{1200}$ of an inch in diameter for the best New Orleans or Gulf, and $\frac{1}{2000}$ for the best Sea Island, which is raised in the United States?" In upland Georgia cotton raised from seed in 1881 or 1882, by Major J. F. Jones from seed carefully selected of the first picking, and the most perfect bolls, the cotton fiber is beautifully developed, clear in its outline, full of oil deposits, and a good spirality producing one and one-fourth bales per acre, when before the war one-half hale per acre was considered a good yield."

[46a] Captain Speer, the Director, kindly allowed me to use the same.

[47] The low percentage of the Wellborn is probably due to an undue amount of earth which covered one of the rows.

[48] J. B. Stephens in Texas Farm and Ranch, June 1, 1889.

EXPERIMENT OF R. D. BLACKSHEAR.

Experimental Plats of Cotton, with chemicals under rows in light lines.

Pear trees, 20 feet apart, with corn between trees.

10 feet wide. 3⅓ feet

No. 1	2	3	4	5	6	7	8
No. 4. Kainit.	No. 4. Cotton Seed Hull ashes.	No. 2. Muriate Potassium.	No. 4 Sulphate of Magnesium.	No. 5. Cotton Seed Meal.	No. 4. Chloride of Lime.	No. 3. Sulphate of Iron.	No. 3. Alum.

25 feet long.

Pear trees.

9	10	11	12	13	14	15	16
No. 2. Sulphate of Copper.	No. 6. Chloride of Sodium.	No. 1. White Arsenic.	No. 1. Verdigris.	No. 4. Lac Sulphur.	½ Gal. Carbolic Acid in 2 buckets of water.	No. 5 Lime.	No. 6. Salt and Lime.

Pear trees.

17	18	19	20	21	22
No. 4. Lime and Sulphate of Copper, dry.	No. 4. Lime and Sulphate of Copper, solution.	100 lbs. Manure.	Subsoiled. No Fertilizer.	No 4. Salt and C S. H. Ashes.	No. 4. Salt and Kainit.

RESULTS OF EXPERIMENTS.

		June 6, 1889.		July 6, 1884.			Aug. 6, 1889.		
		No. of plants alive.	Average height in inches.	No. of plants alive.	Average height in inches.	No. dead plants inside rows.	No. of plants alive.	Height in inches.	Sept. 1, 1889 — No. of plants alive.
1	Kainit	60	12	60	40	9	29	45	14
2	C. S. H. Ashes	60	14	50	36	13	18	41	10
3	Muriate of Potassium	60	10	51	33	6	20	39	8
4	Sulphate of Magnesium	60	16	51	37	7	21	45	6
5	Seed Meal	60	12	55	40	2	28	28	11
6	Chloride of Lime	Small	3	27	10	18	27	26	27
7	Sulphate of Iron	60	15	49	36	15	15	40	5
8	Alum	60	14	37	29	8	3	40	1
9	Sulphate of Copper	60	12	53	33	9	32	39	8
10	Chloride of Sodium	*52	11	51	38	1	22	48	12
11	White Arsenic	*45	10	45	40	2	32	48	15
12	Verdigris	60	15	56	42	3	23	48	10
13	Lac Sulphur	60	14	52	39	7	27	48	15
14	Carbolic Acid in two buckets of water	*60	10	60	42	14	41	48	17
15	Lime	60	13	59	36	4	23	37	10
16	Salt and Lime	*60	14	44	36	13	13	42	2
17	Lime and Sulphate of Copper, dry	60	14	52	35	4	31	40	10
18	Lime and Sulphate of Copper, solution	60	14	42	35	10	4	36	1
19	Manure	Fine 60	17	51	48	17	6	48	4
20	Nothing	Good 60	15	53	36	4	14	48	6
21	Salt and C. S. H. Ashes	*60	11	58	38	6	20	48	13
22	Salt and Kainit	*60	11	50	36	1	14	42	8

* Irregular in growth.

NAVASOTA, TEXAS, September 14, 1889.

Professor F. A. Gulley:

DEAR SIR:—I send you herewith my copy of the "experimental plats," showing condition of cotton throughout the season, observations being recorded on the sixth of each month. "Root-rot" began about the fifteenth of May in adjoining rows to experimental plat, a few plants only being affected on the sixth of June. No plants were found dead in the plats, but soon afterwards; began to die very fast from the fifteenth to the last of June. During July it died very rapidly, and by the first of August half of the cotton was dead, many bolls of the dying cotton having matured and continued to open. The living plants continued to grow till the middle and latter part of August, when it reached its full growth. In most plats the growth has been very uniform, except in No. 6 (Chloride of Lime). In this plat the young plants turned brown soon after coming up. I thought it was dead, and replanted on the eighteenth of May. The second came up well, but soon turned brown. It was left in this condition, and on June 6 was about three inches high, and growing a little. The plat was chopped out leaving twenty-seven plants, one-third of what was left on the others. It grew slowly, making only a few bolls to the plant. Not a plant of it has died. The roots of some of the green plants have a white mold near the surface of the ground, but the root is not dead, as are other cotton plants when affected with "root-rot."

It may be that chloride of lime properly applied may have some beneficial effect, but the growth is slow and little fruit was made.

Continued cultivation on the same field certainly increases the disease with each succeeding year.

Cotton in plat 19, heavily manured with barnyard manure, made rapid growth, and reached a height of forty-eight inches, but when the plants began to die they died rapidly; only four plants are now living. This plat made no more cotton than the others; in fact there is very little difference in the yield. On a space of over one acre, including the experimental plat of ground, nearly all the cotton has died, not more than five per cent being alive now. About fifty of my young pear trees have died on the same ground where cotton has, and from the same cause. Most of the trees have died since the first of July.

In conclusion, I don't know as we have gained any definite knowledge about the use of fungicides and "root rot," unless chloride of lime is of some benefit.

Yours, respectfully,

R. D. BLACKSHEAR.

Experiments were also made by Mr. E. S. Peters, but "root-rot" did not appear to any great extent in the treated as well as the untreated plats, so that the experiments were of no value.

It should be stated in this connection that the claim made by some, that the disease does not always reappear in the same spot, though the ground is planted with cotton, is partially confirmed by the experiments of Mr. Peters, and also by what I have seen at Millican. In 1888 affected plants were found here and there in a patch of cotton. None was found dead in this patch on the twenty-fifth of June, though it is not improbable that some may have died later. Several rows of corn were planted near one end of a patch where most of the cotton died the year previous. In most cases, however, the disease regularly reappears on the same ground, as I have observed at Navasota, Calvert, Ennis, Dallas, Sherman, and Melissa.

The distribution of parasitic fungi is sometimes peculiar and not at all understood. A curious case is reported by Kuehn.[49] The Violet-root fungus (*Rhizoctonia Medicaginis*) did much injury to mangolds near Bunzlau, Germany, from 1848 to 1854, some years worse than others. From 1854 to 1858 it was not again observed.

THE USE OF FERTILIZERS AND MANURE.

In Bulletin 4 I expressed an opinion, from some observations made, that barnyard manure would prove valuable. The experiment of Mr. Blackshear, however, shows that when the soil is filled with the fungus that the disease can not be prevented. In fact all but four plants died in the plat so treated. On the 20th of June, when some observations were made on the condition of cotton in the experimental plats at Navasota, the plat treated with barnyard manure had a perfect stand and not a single stalk was dead, while plants in the check row were dying in large numbers. The treated cotton had a much greener shade, and was growing much more vigorously. See second and fourth columns of Mr. Blackshear's report.

Of the fertilizers Kainit has proved most beneficial, fourteen plants remaining alive on September 6. Many correspondents in other cotton States mention Kainit as valuable in checking the disease. Both common salt and salt and cotton seed hull ashes had respectively twelve and thirteen plants alive September 6.

Mr. Blackshear has referred to the effectiveness of Chloride of Lime. It

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[49] Die Krankheiten der Kulturgewæchse, ihre Ursache und ihre Verhutung, Berlin, 1858, p. 232.

is also interesting to note that Lac Sulphur, White Arsenic, and Carbolic Acid are more effective than any other substance with the exception of Chloride of Lime.

If the soil is comparatively free from the *Ozonium*, and then a free application of barnyard manure, wood ashes, Kainit, are used to give young plants a good start, the disease can no doubt be materially checked.

ROTATION OF CROPS.

The class of diseases to which "root-rot" of cotton belongs can no doubt be largely governed by a judicious method of cultivation. Is it surprising when cotton is grown year after year on the same soil that a diseased stand should appear? When crops are grown successively on the same soil for years parasites of all kinds become more numerous, and finally the crop will not grow at all. Many insect pests can not be destroyed in any other way except by rotation of crops. So with "root-rot" diseases; it is very difficult to reach the fungus with a fungicide, as anything which is likely to kill the fungus will act injuriously on the tissues of the plant.

HOW AND WHAT PLANTS TO BE USED IN ROTATION.

In rotation of crops care must be taken not to use such plants upon which the fungus grows. They have been given elsewhere in this Report. Corn, sorghum, millet, wheat, oats, and other members of the Grass family do not die from this cause, and consequently should be used after cotton. The plants to be used will depend somewhat on the locality. In Northern Texas all of these will do, but in South Texas wheat and oats are not a success, owing to "rust," but corn, sorghum, and millet, and grasses do well, and can be used with advantage. Mr. W. W. Stell[50] says: "The proper way to farm, in my opinion, is to third our crops; plant one-third corn, one-third small grain and the grasses, and the remaining third in cotton. Plant corn after cotton, and cotton after small grain, and small grain after corn. As soon as the corn is gathered run your stalk cutter and otherwise prepare for small grain, and in August and September, while there is a green coat of vegetation on the stubble, turn it under as deep as possible. Up to 1884 I had a certain tract of one hundred acres on my plantation planted almost entirely in cotton for several years. The cotton died more and more on it each year. In 1884 I planted the one hundred acres in oats; in 1875 I planted in cotton, and made more than one five hundred pound bale to every acre, and not a dead stalk on the one hundred acres. I then kept up planting cotton on it for a few years, and the cotton began to die. In 1881 I planted the one hundred acres in wheat, and in the spring of 1883 I had a good volunteer stand of wheat and let it stand, so that this land was in wheat two years. Since then it has been alternated in cotton and corn, and not one dead stalk have I ever seen on it since it was planted in wheat."

Mr. H. R. Von Bieberstein writes as follows: Rotation of crops will counteract to a very great extent. The best plan is to introduce a three year rotation. Divide your field in three parts, plant one part in cotton, one part in small grain, oats and millet; rye and wheat being to uncertain. Small grain will be removed in June; in the summer you will find time to manure the land and plow. This can then be put in with fall crops, such as Irish potatoes, or rye, using it for winter pasturage, and in the spring cotton should be planted; in the third year plant corn. In this way the disease can be reduced to a trifle.

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[50] Texas Farm and Ranch, February 15, 1889.

TREATMENT OF FOREST AND APPLE TREES.

In this case we can only suggest preventive manures. Where fields are affected with the Violet root fungus, ditches are dug, as deep as the roots extend, to prevent it from spreading. In *Rosellina Quercina*, the fungus attacking seedling oaks, and *Agaricus melleus* similar measures have been proposed and used very successfully in Europe. In orchards and nurseries where the *Ozonium* occurs this method can be applied. The following from Von Thuemen[51] on "the root mold of the grape vine" is applicable to "root rot" of apple and forest trees caused by *Ozonium.* "In the greater number of cases man himself is the guilty party—the keeping clean of the soil being only too often grossly neglected. Upon the surface, indeed, the industrious and methodical vineyardist does not fall into error so easily, since several times a year the entire vineyard will be carefully cleaned and weeded. But this alone does not long suffice; the deeper portions of the soil must also be carefully cleaned, and this unfortunately is almost everywhere slighted, probably entirely neglected. If the branches and twigs lying in the open air form a most favorable soil for those tender white fungous threads, how much more must the same objects favor their growth when buried deep in the earth, where the air supply is so much more scanty." Orchards, vineyards, and nurseries should be kept rigidly clean; the rubbish should be destroyed. Any trees dying from "root-rot" should at once be taken up and burned. The place where the trees stood should not be replanted again, until sufficient time has elapsed for the fungus to disappear (from three to five years).

When trees are purchased every precaution should be used not to plant those which have come from an infected nursery. Care should be used in planting sweet potatoes; do not set out plants which have come from an infected spot, or even near it, as in digging potatoes threads of the fungus may remain to the hoe or plow, and thus the disease is often carried to remote parts of the field The greatest care should be taken not to carry infected plants from field to field, as a small thread of the fungus falling from the root is a starting point for the fungus, and the disease appears, much to the surprise of the farmer, where he did not expect it.

Weeds, especially the Common Sida, no matter whether occuring in cotton fields, in orchards, or grain fields, should not be tolerated, for these certainly harbor the fungus.

SUMMARY OF ANSWERS TO POSTAL CIRCULAR.

The following circular postal card was sent out by the Experiment Station:

1. Please make an approximate estimate of the amount of cotton dying in your county from "root rot," variously called "dead land," "alkali," etc.?
2. What is the character of the soil?
3. What plants die from the same cause?
4. Have you noticed any weeds apparently dying from the same cause?
5. Will you please mail parts of root, stem, and leaves to me of plants which are dying?
6. Do these spots seem to increase or diminish in size when rotation of crops is practiced?

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[51] Die Bekæmpfung der Pilzkrankheitien unserer Culturgewæchse (Versuch einer Paflanzentherapie zum praktischern Gebrauche für Land und Forst wirthe, Gærtner, Obst und Weinzüchter). Vienna, 1886, p. 157. A good English Abstract by E. F. Smith, Journal of Mycology, Vol. V, p. 107; also Abst. Sorauer Just Bot. Jahresbericht, 1885, p. 500.

7. Has the application of commercial fertilizers, wood ashes, or barnyard manure proved beneficial?

8. Have you drained any of these dead spots? If so, does it seem to alleviate the trouble?

9. Does subsoiling have a beneficial influence?

10. Have you noticed the falling over of corn, sorghum, oats, or wheat when grown on these "dead spots"?

Remarks..

Yours respectfully,

Ames, Iowa. L. H. PAMMEL.

1. Fifty-seven replies have been received, representing forty-seven counties. The percentage of loss varies from one-tenth of one per cent in Smith county, to twenty-five per cent in Fayette. Four to five per cent represents the average loss in counties like Bell, Ellis, Grimes, and Washington. The loss computed on the percentages given by correspondents amounts in round numbers to one million dollars.*

2. Soil: Hard clay, deep sandy loam, heavy black waxy, black sandy, mesquite lands, red mulatto, yellow alluvial, shelly land, orange drift, and chocolate.

3. Cotton, sweet potatoes, watermelons. sweet peas, tobacco, cow peas, Irish potatoes, okra, Apple, Pear, Black Ash, Pecan, Bois d'Arc, Mulberry, China, Black Locust, Peach, Walnut trees, and Rose bushes.†

4. The following weeds have been noticed: Cocklebur and Careless (*Amarantus, Boerhaavia*).

6. Of the fifty-seven replies received, twenty-two say that when rotation is practiced the disease diminishes, while four have seen it increase.

7. Manures and fertilizers are not generally used, only sixteen having tried them, eleven of which have had good results with barnyard manure, and five with wood ashes and potash.

8. Only four have drained, and that only by ditching and subsoiling; six find that drainage relieves the trouble.

9. Ten find that subsoiling will relieve, while four believe it is a disadvantage. The others have had no experience.

10. Forty-two have never seen corn, sorghum, oats, or wheat fall over when it follows cotton. Four find that sometimes it does, and will not produce much. In some cases the falling over is due to the chinch bug.

REMARKS.

J. N. Rose: "Dies worse after wet weather, and begins on the tap root, while the lateral roots take it later. Frequent rains keep surface roots alive."

J. B. Tanner: "This year cotton died more than usual, as we had a wet spring and summer."

T. M. Scott: "The limestone underneath gives good drainage."

W. P. Miles: "The rot in cotton has been worse than any previous year. Our spring was one of more than ordinary rainfall until the tenth of July, then a drouth till the sixth of September. Sweet potatoes are affected with a dry rot, first making its appearance on the outside of the tuber. A white

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*Based on L. L. Foster's Report for 1887.

†I have noticed the following: *Gossypium herbaceum*, *Ipomœa Batatas*, *Dolichos Sinensis*, *Pyrus Malus*, *Fraxinus Americana*, *Morus alba*, *Melia azedarach*, *Broussonetia papyrifera*, *Sida spinosa*, and *Ambrosia psilostachya*.

spot of mold precedes decay. This spot becomes brown, and penetrates the potato."

John P. Lair: "The land upon which cotton dies need not be planted to apple trees and sweet potatoes, as they will take the disease. Peaches will do well in such places."

W. P. Darby: "The spots diminish when rotation of crops is practiced. I have reinstated the worst patches on my farm by planting corn for a few years, and turning weeds and all under, allowing it to rot. My experience is that where cotton dies it makes good corn, but the stalk will fall soon after it is mature."

Geo. H. Hogan: "Corn seldom falls over; when it does it is due to chinch bugs."

T. V. Munson: "Ten or more years ago I saw a circular 'patch' of weeds, Osage hedge, vegetables, etc., killed. The disease spread in concentric rings for two or three years from an original undrained basin. A fruit grower here found that peach trees planted upon a flat rock laid on surface of soil, then mounded up, did well; but when set in the ordinary way 'root rot' would set in, the locality being seapy."

Nat Stevens: "Constant deep plowing in the fall lessens the trouble."

L. W. Moore: "Rotation will check the disease, using millet, sorghum and corn, then cotton."

W. G. Crockett: "Sweet potatoes seem to distribute the disease through the soil. Cotton always dies after it."

SUMMARY.

The soil upon which the disease occurs is very variable. It is worse on the black cretaceous soils. These are very poorly drained. Wet seasons, and especially rain followed by hot sunshine, is favorable for the disease. The character of the forest growth has nothing to do with the disease. It occurs alike on the mesquite soils of Travis and Hays counties and the post oak lands of Eastern and the bois d'arc lands of Northern Texas. The various theories are not founded on scientific facts. Chemical analysis of the soil does not show any appreciable difference in soils where cotton dies and where it does not. "Alkali," as the term is used, is very vague, and does not apply to the Texas soils where cotton dies. Fibrous-rooted plants suffer from "alkali" in California and other places. In California cotton succeeds admirably on such lands. The fibrous-rooted plants, like grasses, do not die from "rot root" in Texas. "Seedling rot" and "sore shin" should not be confounded with "root-rot." "Seedling rot" only affects young plants. The "Bacterial Disease of Corn" sometimes occurs in fields where cotton died the previous year from "root-rot," but is entirely distinct from "root-rot" of cotton, sweet potato, etc.

"Root-rot" of cotton is caused by a parasite—*Ozonium auricomum.* The fungus has been found on all roots which have died from this disease. Plants should be examined before they have wilted; in such cases a white mold-like fungus, the early stage of *Ozonium*, will be found on the surface of the roots as well as in the meduallary rays and vessels. Threads of the *Ozonium* were taken, and young plants in pots were inoculated. These died of the disease. Wart-like bodies are found on the roots of cotton and other plants affected. These are masses of the fungus, and retain vitality for a long time. A large number of plants are affected, as sweet potatoes, apple, and some forest trees; also the Common Sida. On some of the roots of apple trees *Schizoneura lanigera* occurs. The *Schizoneura* and *Ozonium* occur independent of each other. The *Ozonium* does not produce the knotty bodies.

The *Ozonium* prepares the way for a large number of saprophytic fungi, like *Mucor* and *Penicillium*, and unless care is taken wrong conclusions may be formed. A fungus has been isolated from rotten sweet potatoes, but it is not definitely settled whether it is connected with *Ozonium* or not. It is capable of producing rot in sweet potatoes and young cotton.

The lint from plants affected with "root rot" is much inferior in quality. Seeds from diseased stalks showed good capacity for germination.

Treatment.—Fungicides have not checked the disease, except Chloride of Lime, and where this was used no cotton was produced.

Rotation of crops is practically the only thing, so far as I know, which will stop the disease. Members of the grass family are to be used, allowing three years to intervene before cotton is again planted. Care should be taken not to obtain plants of any kind from an infected nursery or field.[52]

In conclusion, I wish to thank the various planters and numerous correspondents who have given me assistance in prosecuting the work.

L. H. PAMMEL.

Ames, Iowa, January 6, 1890.

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[52] Articles on cotton "root-rot." It is not intended to be complete as I have not been able to see all of the agricultural papers, where much that has been written on the subject has appeared. Crockett, Willis G., Losses in Cotton Culture, Texas Farm and Ranch, April 15, 1889; Dabney, W. S., Cotton Blight, Texas Farm and Ranch, Feb. 15, 1889; Derrow, A. N., Practical Hints on Cotton Raising, Am. Agriculturist, 1866, p. 133; Fruit Growers' Journal, Oct. 1, 1888; Hinkle, C. F., Cotton Blight, Texas Farm and Ranch, Jan. 1, 1889; Hinkley, Dr. H., Cotton Culture—Costs and Risks, Am. Agriculturist 1866, p. 433; J. M. H., Poisons Soils of Texas, Coleman's Rural World, May, (?) 1878; J. M. Q., Root Blight in Young Apple Trees. Coleman's Rural World, March, (?) 1878; Loughridge, Dr. H. H., Tenth Census Report, Cotton Production in the United States, Vol. V, Special Report of Texas; A. W. Kerr, Cotton Blight, (?) Texas Farm and Ranch, Sept., 1886; Meitzen, Herman J., Cotton Blight, Texas Farm and Ranch, Nov. 1, 1888; Morrow, Dr. W. B., "Cotton Blight" or "Root Rot," Texas Farm and Ranch, April 1, 1889; Root Rot, Texas Farm and Ranch, Oct. 1, 1889; Pammel, L. H., Root Rot of Cotton or "Cotton Blight," Bulletin No. 4, Texas Agricultural Experiment Station, Dec. 1888; Abst. Agricultural Science, 1889, p. 100; Bot. Gazette, Vol. XIV, p. 113; Humphrey, Bot. Centralblatt, Vol. XL, p. 59; N. O. Atwater in Digest of the Annual Reports ports of the Agricultural Experiment Stations of the United States for 1888, Bulletin No. 2, Department of Agriculture, p. 189; Texas Farm and Ranch, Nov. 1, 1889; Root-Rot of Cotton or "Cotton Blight," Texas Farm and Ranch, Sept. 1, 1889; Ramsey, A. M., Soil for Orchards in Texas, Coleman's Rural World, May 1, 1878; Stell, W. W., "Cotton Blight," Texas Farm and Ranch, Feb. 15, 1889; Stelle, J. P., Fourth Entomological Report, Appendix III, p. 25; Stephens, J. B., Cotton Blight, Potato Blight, Texas Farm and Ranch, Jan. 1, 1889; Stringfellow, H. M., Cotton Blight, Texas Farm and Ranch, Feb. 15, 1889; Texas Farmer, September, 1888; Texas Farm and Ranch, August, September, and October, 1886, April 15, 1889; Wellborn, Jeff, Root Rot or Blight, Texas Farm and Ranch, July 15, 1889; The Practical Farmer vs. the "Ologist," Texas Farm and Ranch, Nov. 1, 1889; Red Rust in Cotton, Home and Farm, Louisville, Ky., August 1, 1889; Yoakum, Dr. F. L., Texas Farm and Ranch, October 7, 1886; Texas Farm and Ranch, September 1889.

March 15, 1890.—The following additional articles have come to my notice since the above was written: W. R. Cole, Texas Farm and Ranch, Dec. 1, 1889; Cotton Blight, Texas Farm and Ranch, Dec. 15, 1889; Farm and Home, Springfield, Mass., Oct. 1, 1889; Wm. Lomas' Review of Dr. Yoakum, Texas Farm and Ranch, Feb. 15, 1890; W. B. Morrow, A Criticism, Texas Farm and Ranch, Aug. 15, 1889; Texas Farm and Ranch, Harvesting and Saving Sweet Potatoes, articles by H. M. Stringfellow, W. B. Morrow, J. W. Simmons, and C. N. Eley, two articles on Root-Rot by Jeff. Wellborn, Dec. 15, 1889, and Jan. 15, 1890; Dr. F. L. Yoakum, The Root Blight of Tap Rooted Exotic Plants, Texas Farm and Ranch, Jan. 15, 1890.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Showing depressions and fungus at *d.* Adventitious buds at *b.* (Original).

Fig. 2. A, diseased root, showing fungus strands *f*, somewhat exaggerated. Enlargement at *e.* *r.* roots at the enlargment. B, portion of a root covered with fungus threads. Brown pseudo-sclerotia at *p.* C, diagramatic section of *p*, showing fungus threads. (Original).

Fig. 3. *a*, galls on apple roots; *b*, apterous, female, showing cottony covering; *c*, winged individual; *d*, leg; *e*, beak; *f*, *g*, antennæ. (After Riley).

PLATE II.

Fig. 1. *Sida spinosa*, slightly reduced.

Fig. 2. End of a small branch of *Sida spinosa*, natural size. Both figures drawn by Miss Mattie H. Hoke.

Fig. 3. Strands of *Ozonium auricomum*, Lk.; *a*, showing branches of the strands, with fine thread-like branches coming from the larger ones; *b*, the small threads more magnified, showing mode of branching. From photographs by Dr. M. Francis; *a*, magnified about 100 times; *b*, 200 times. Drawn on plate, from the photographs, by Miss Mattie H. Hoke.

PLATE III.

Fig. 1. *a*, part of a strand of the fungus, showing cells with a branch coming from it, with the ultimate sharp-pointed branches shown at *b.* B, a young strand with a branch going out from it. Both figures magnified 375 times. (Original).

Fig. 2. *a*, spore from Fig. 4, *s*, germinating after 48 hours; *b*, an enlargement in one of the threads; *h*, hypha, with vacuoles; *e*, part of one of the hyphæ with a second kind of spore. Magnified 375 times. (Original).

Fig. 3. Some of the cells of a rotting sweet potato, showing starch grains, *x*; *l*, black, perithecium-like body, lying over the cell; *m*, the mycelium between the walls of the cells. Magnified 450 times. (Original).

Fig. 4. Perithecium, *p*, from culture of sweet potato which containea the black perithecium-like bodies shown in Fig. 3, *l*; *c*, fungus thread with a spore-like body, from cultures; *s*, spores; the upper part of the perithecium broken, and the cells lengthened out. (Original).

PLATE IV.

Fig. A. A, diseased boll; B, boll from a healthy plant, opened. Bolls furnished to me by Mr. Geo. H. Hogan, Ennis, Texas. Grown on the same soil, a short distance apart. From a photograph.

PLATE V.

Fig. 1. Fibers from a diseased plant, magnified 375 times. (Original).

Fig. 2. Fibers from a healthy plant, magnified 375 times. (Original).

Fig. 3. *Verticillium*; *b*, strand; *s*, spores; *c*, hypha; the fruiting branches are borne at the end. (Original).

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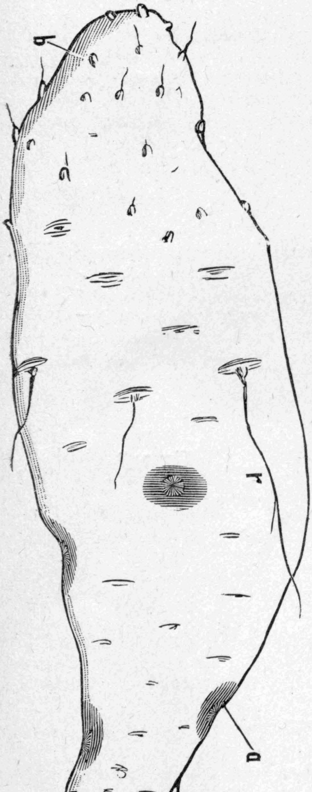
PLATE I.



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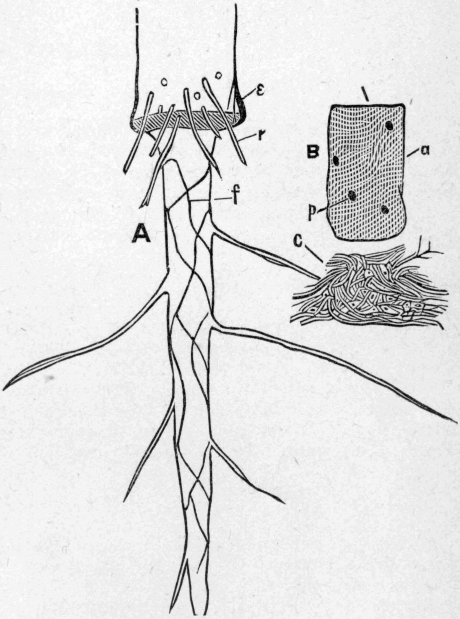

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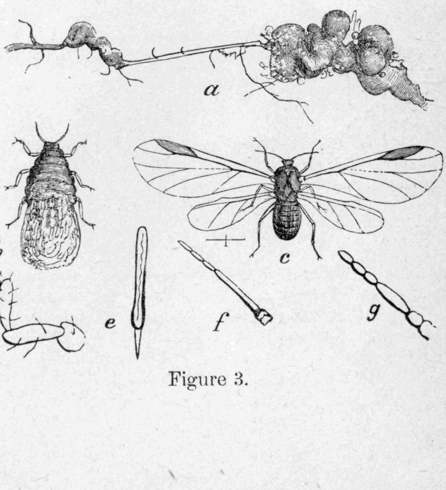

Figure 3.

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"Cuts of Bulletin #7."

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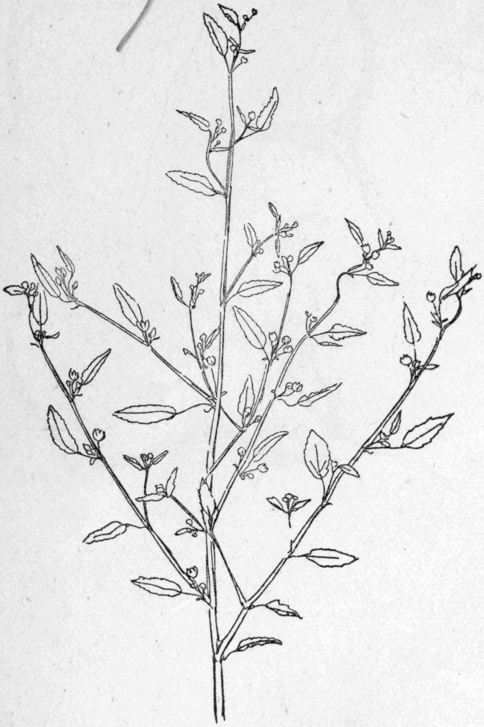


Figure 1.

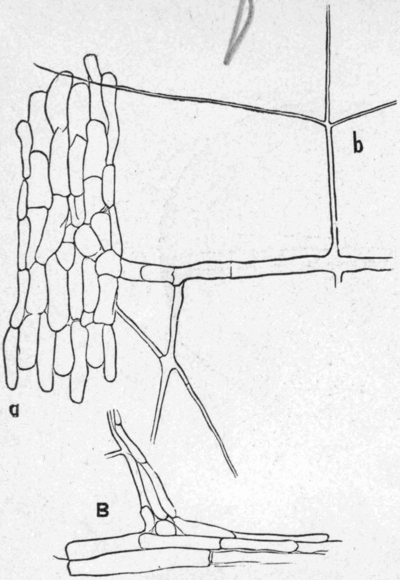
Figure 2.

a *b*

Figure 3.

"cuts of Bulletin #7."

PLATE III.



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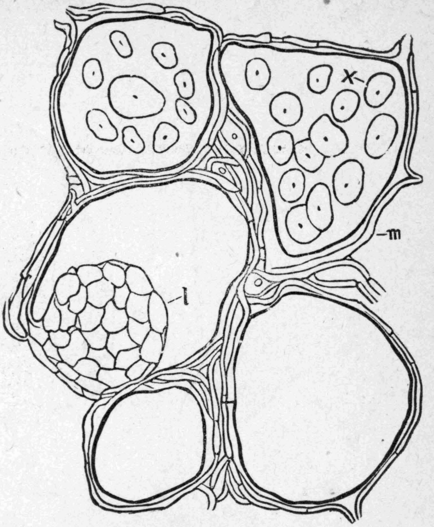

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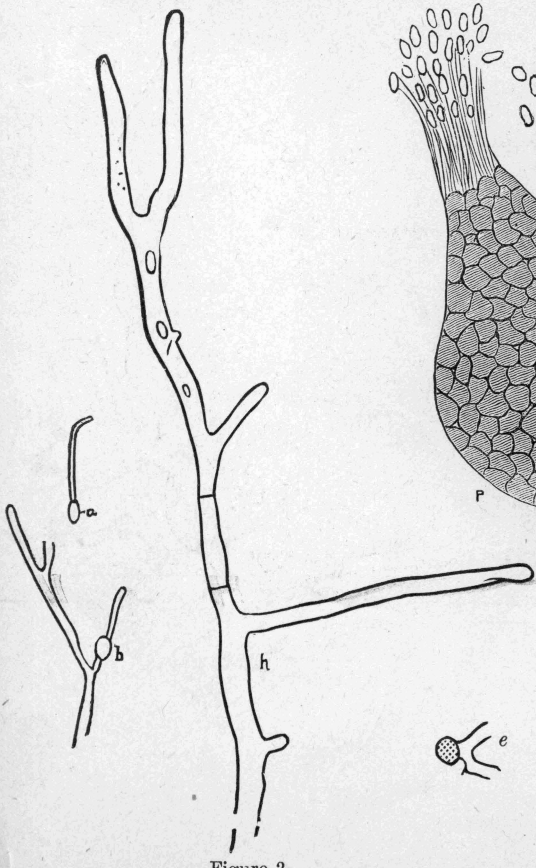

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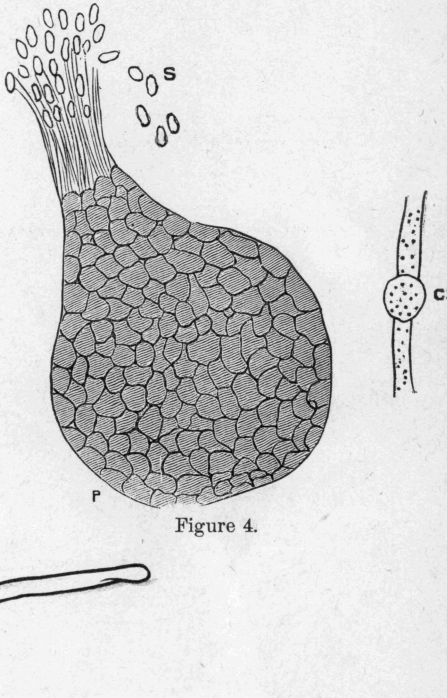
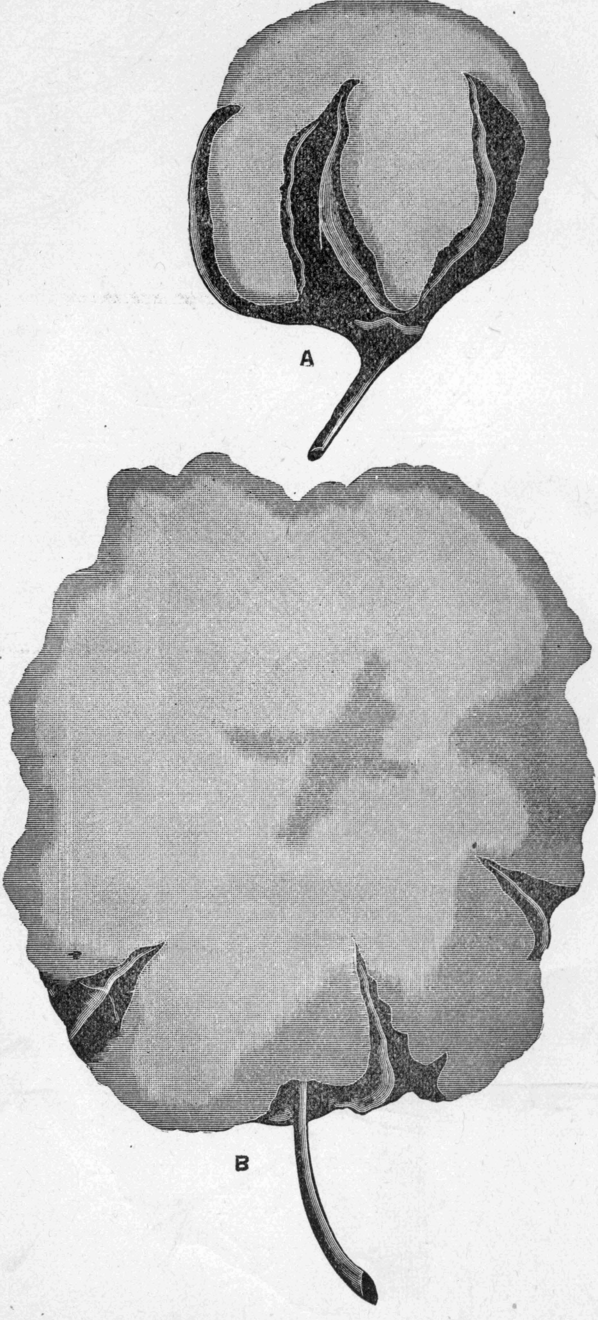


Figure 4.

Cuts of Bulletin #7."

PLATE IV.



A

B

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PLATE V.

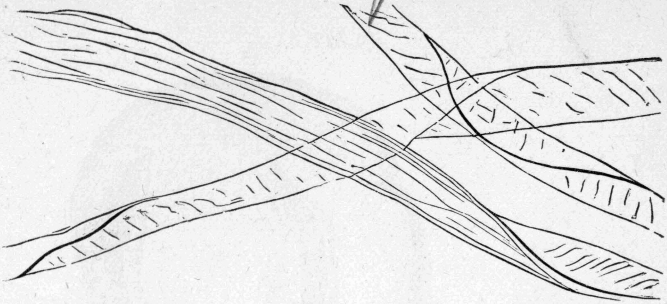
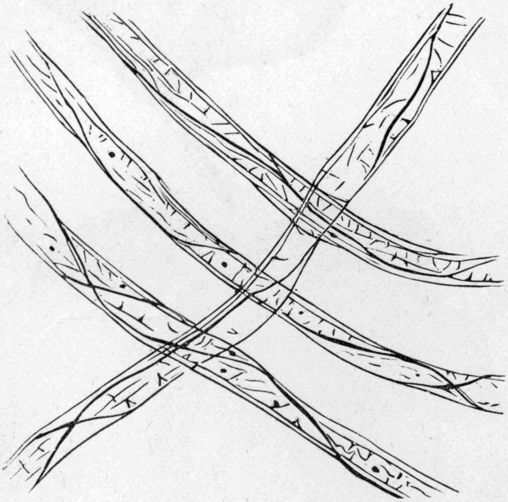


Figure 1.



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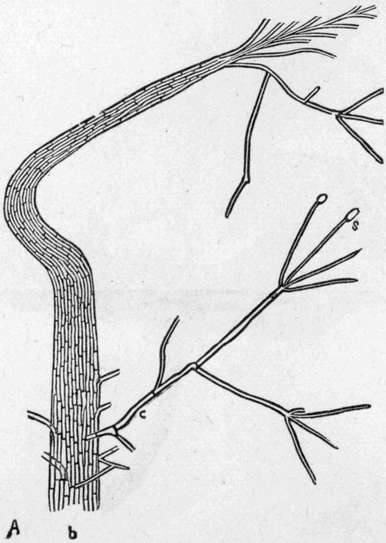

Figure 3.