SOILSTAIN, OR SCURF, OF THE SWEET POTATO

By J. J. TAUBENHAUS,
Associate Plant Pathologist, Delaware Agricultural Experiment Station

INTRODUCTION

Soilstain of the sweet potato (Ipomoea batatas) is a disease which is little known. The present work is the result of three years' investigations by the writer.

The disease was first described by Halsted (3) in 1890 under the name "scurf." For the last 24 years nothing new has been added to our knowledge of this trouble; subsequent writers have merely quoted Halsted. From the writer's studies (8, 9) it became evident that the disease needed further elucidation. The average grower little suspects that "stain" is a fungus trouble. In fact, the term "soilstain" as applied by the grower indicates his belief that there is something in the soil which stains the roots. He even believes that the plant itself leaves some coloring matter in the soil which stains subsequent crops of this valuable root. Others think that the staining is due to the application of manure to the soil; hence, they term it "manure stain."

ECONOMIC IMPORTANCE OF THE DISEASE

Soilstain is not a disease to be feared in the sense that it may produce a direct rot in the mature roots; nevertheless, it is economically important. Growers whose lands are badly infected assert that stained roots keep better in storage. Others find consolation in saying "there is no such thing as stain, the dark color of the skin being merely a varietal characteristic." The fact remains, however, that many eastern markets discriminate against stained roots. In years of overproduction the New York market refuses stained roots. The western buyers, on the contrary, are lax on this point; otherwise, many growers in the United States would be forced to cease producing sweet potatoes for want of a market.

OCCURRENCE OF SOILSTAIN

Soilstain is prevalent in Delaware on practically all sweet-potato land. It has also been reported from other States where sweet potatoes are grown. The writer has met with it in the sweet-potato districts of Delaware, New Jersey, Maryland, and Virginia.

The Editorial Committee of the Journal of Agricultural Research kindly forwarded to the writer a copy of Harter's paper on "Sweet-Potato Scurf" before it was published, with the suggestion that reference to that article be made. The writer has covered certain studies on the scurf of the sweet potato in storage and has treated more fully the morphology and physiology of the fungus than has Harter. These studies verify the work of Harter with one exception; in the morphology of the fungus he overlooked the fact that the conidia are catenulate.

The writer is indebted to Dr. Charles Thom, of the Bureau of Chemistry, and Mrs. Flora W. Patterson, of the Bureau of Plant Industry, for having examined specimens of this fungus.

SYMPTOMS OF SOILSTAIN

Soilstain is characterized at first by small, circular, deep-clay-colored spots on the surface of the sweet-potato root. These spots occur singly, but usually there are several in a given area. When very numerous, the spots coalesce, forming a large blotch which sometimes takes the form of a band or may cover the entire root. Soilstain is particularly conspicuous on the white-skinned varieties, such as the Southern Queen. Here the color of the spots is that of a deep-black clay loam. On the darker-skinned varieties the color of the spots does not appear so conspicuous. Soilstain is a disease of the underground parts of the plant. The vine and foliage are never attacked as long as they remain free from the soil. However, when these are covered, the petioles as well as the stems become infected.

EFFECT OF THE DISEASE ON THE HOST

After several months of storage, badly affected roots become a dark brown, which greatly contrasts with noninfected sweet potatoes. Occasionally, badly stained roots seem to be subject to more rapid drying and shrinking. This, however, is not often the rule. Usually soilstain is very prevalent in overheated storage houses. It may be, therefore, that the rapid shrinkage is due to the overheating and not to the effect of the disease itself. More data are necessary to determine these points. Soilstain is not only a disease of the epidermis (Pl. LXXXVII, fig. a) and as such considerably reduces the market value of mature roots, but it also attacks the very young rootlets, preventing their further development and indirectly reducing the yield. In badly affected fields the writer has estimated a loss of 10 per cent of the crop from rootlet infection.

FACTORS FAVORABLE TO SOILSTAIN DEVELOPMENT

The type of soil seems to be a determining factor in the development of soilstain. Sweet potatoes grown on very light sandy soils, especially those which are hilly, are usually free from the disease. The heavier lands, or those rich in humus, rarely produce a clean crop. The application of manure favors the spread of the fungus and increases the stain. In fact, the manure itself is often a carrier of the disease, since diseased roots of all sorts find their way ultimately to the manure pile. The trouble is also carried directly with the seed stock. These, when planted in the seed bed, will produce 100 per cent of diseased sprouts. Experimental data, as well as extensive observations in seed beds and in the field, all corroborate these statements. Wet weather is favorable to the spread and increase of stain. During wet seasons the disease is more plentiful than in dry seasons.
STORAGE EXPERIMENTS

Growers who do not suspect the fungous nature of soilstain are always at a loss to explain the appearance of the trouble in storage when otherwise healthy roots are brought in. In order to determine definitely the effect of storage on this disease, the following experiments were carried out during two consecutive seasons: At digging time in September, 1913, a diseased field was chosen for that purpose. A large number of roots were selected and placed in hampers in the following ways.

Experiment 1.—Three hampers were filled with roots which to all appearances were free from stain. The object of the experiment was to determine whether apparently clean roots taken from a diseased field will develop stain.

Experiment 2.—Three hampers were filled with roots which showed very slight infection. The spots in these cases varied from 5 to 10 in number and were single and scattered. The object of this experiment was to determine whether the disease would increase in storage and the spots coalesce.

Experiment 3.—Three hampers were filled with roots which were thoroughly stained all over. The object of this experiment was to determine whether badly affected roots would be subject to more rapid drying and shrinkage.

Experiment 4.—Three hampers were filled with well-stained roots. At the bottom was placed a layer of stained roots, followed by a layer of healthy ones, on top of which was another layer of stained roots. Each layer was separated from the other by a narrow strip of paper. The object of this experiment was to determine whether healthy roots in contact with diseased ones will become infected under storage conditions.

Experiment 5.—Three hampers were filled with roots which to all appearances were free from stain and were taken from an adjoining clean field. These were to serve as checks.

All the experimental hampers were placed in a medium-sized potato house which had poor facilities for ventilation. The conditions, therefore, were ideal for the experiment. The hampers were stored for a period of 4 months.

The results of the above experiments may be summarized as follows: The roots in the first three hampers (experiment 1) remained clean, indicating that clean roots, though coming from an infected field, when stored and protected from contact with stained roots, will remain clean. The roots in the second three hampers (experiment 2) showed an increase in the stain and a coalescence of previously smaller spots. The roots in the third three hampers (experiment 3) seemed to be shrunken most. The roots in the fourth three hampers (experiment 4) indicated that apparently healthy potatoes may become stained when placed directly in contact with diseased roots. The check roots (experiment 5) were all free from stain. The above experiments were repeated in 1914 and 1915. The results obtained did not differ from those referred to above.
HALSTED (3) was first to attribute the cause of soilstain (scurf) to a fungus, Monilochaetes infuscans E. and H. However, Halsted and the later writers have left no record of having experimentally proved the pathogenicity of the fungus. The writer has found no records of its having been grown in pure cultures. Several efforts by the writer to obtain the organism from badly stained roots which were kept in storage at first yielded negative results. Each time the causative fungus was overrun by a varied and rapidly growing flora. Pure cultures of the fungus were finally obtained from plantings of young minute spots. Of 300 such spots, 10 per cent yielded colonies of the causative organism, and these were few in number. The plates were examined every day and it was found that the fungus did not appear until nearly three weeks after culturing. Because of this slow growth, the fungus in previous work was overrun by secondary invaders. The cultural work emphasized the necessity of making a large number of poured plates when working with an apparently difficult organism. The first reference to the fact that this fungus had been grown in culture was made by the writer (8, 9) in 1914 and also recently by Harter (4). Using pure cultures of the fungus, the writer reproduced the disease several times at will.

MORPHOLOGY AND PHYSIOLOGY OF THE FUNGUS

It has been stated that Halsted first named the organism. Although some figures are recorded in Halsted’s bulletin (3), yet they are only fragmentary and do not take account of all the various stages of the morphology of the fungus. Halsted’s observations of the fungus must have been limited to material on the host. In pure culture the fungus grows very slowly. It is characterized by small darkish round colonies (Pl. LXXVI, fig. 1) varying from one-tenth to one-fifth of an inch in diameter. The growth is floccose at the top, and anastomosed below, having a resemblance to a stroma in the substratum of the medium. The surface growth of a colony resembles that of species of Alternaria and some species of Cladosporium, but differing from these by its restricted slow growth. The surface of the colony of M. infuscans has an ashen color, which is also the general appearance of the fruiting. The fungus grows better on vegetable plugs and is at its best on steamed onion and celery stalks. The aerial mycelium is branched, septate, and hyaline when young (Pl. LXXVII, n, w). With age the mycelial cells turn gray, then black, and become filled with oil globules (Pl. LXXVII, l, r). The submerged hyphae are made up of smaller cells which in old cultures swell and take on the appearance of chlamydospores. The conidiophores are distinct from the mycelium (Pl. LXXVII, a), and not obsolete, as stated by Stevens (7). From extended observations it was found that conidiophores do not arise in clusters, but are always formed singly.
Soilstain, or Scurf, of Sweet Potato

(Pl. LXXVII, a, t, u). They are erect, not branched, and when viewed hastily would be mistaken for setae of species of Colletotrichum or Vermicularia. Upon a close examination they are found to be made of closely septate dark-celled mycelium, the base of which rests on one or two smaller ones (Pl. LXXVII, a). Generally the measurements of the conidiophores vary with the medium used. The host, too, seems to have a determining influence.

In material collected at random from the market or direct from storage the conidiophores appear to be smaller than those taken from artificially infected sweet potatoes. In the latter case, the causative organism seems to possess more vigor, because of moisture under control methods. The average of nearly 500 measurements on various media and on the host shows that the conidiophores vary from 100 to 300μ in length. Great difficulty was experienced in studying the formation of conidia. It is difficult to observe spore formation on storage material. Harter (4) claims that there is but one conidium formed at one time at the tip of the conidiophore. As soon as this conidium breaks off, a new one is formed in its place. The studies of the writer on this point are at variance with those of Harter. The writer finds that the spores are borne in distinct chains. In pure culture the chains break up very readily when moistened and pressed down with a cover glass. The spore chains break immediately when moistened with alcohol, oil, or any other liquid (Pl. LXXVI, fig. 2, k, d, b). The chains of spores do not appear to be held together with any kind of mucilage. However, it was found that when a dry cover glass is carefully placed on the surface of a colony growing in a Petri dish and the latter placed under the microscope, all the stages of spore formation could be studied with much ease. The spores are borne in chains (Pl. LXXVI, fig. 2, a, i, and LXXVII, g, h). At first, the protoplasm of the tip of the conidiophore is seen to round up, then a minute bud pushes out (Pl. LXXVII, c) and increases in size until a mature spore is developed, which is left standing at the tip of the conidiophore (Pl. LXXVII, d). All the succeeding newly formed conidia are formed at the tip of the conidiophore, so that the oldest conidium stands at the farthest end of the chain (Pl. LXXVII, e, f, i). Careful observations of these chains have shown them to be made up of from 10 to 28 conidia. A distinct characteristic of the latter is that they are always guttulate (Pl. LXXVII, m), irrespective of the medium used. In some cases the conidia in pure culture appear to be massed in "pockets" around the tip of the conidiophore, as in species of Gloeosporium or Fusarium (Pl. LXXVI, fig. 2, c, e, g, k, f). However, a close examination will show that this is no definite characteristic of the fungus.

It has been stated that the least disturbance will cause the chains of conidia to break up. In so doing they invariably cluster around the conidiophore, grouping themselves in various ways (Pl. LXXVI, fig. 2,
This is observed only when the fruitings of the fungus are seen in a dry state. However, when placed in a drop of water or in any other liquid, the chains of spores break up and scatter over the liquid. The spores (conidia) are 1-celled, hyaline, with a greenish tinge, but never dark or brown. They measure from 15 to 20 by 4 to 6μ. Sometimes a germ tube is produced at the tip of the conidiophore which later bears spores (Pl. LXXVII, fig. h, j, k, o, p). Broken-off mycelial cells are also capable of germinating. In this case a germ tube upon which spores are formed is first produced (Pl. LXXVII, fig. b). The spores readily germinate in water or in any nutrient medium (Pl. LXXVII, fig. m, q, s, v, x, y, z).

An attempt was made to determine whether *M. infuscans* would also cause a rot of the interior of the sweet-potato root. Inoculations made with pure cultures of the fungus in slits made with a sterilized and cooled scalpel showed the organism incapable of causing a rot of the root. It was thought that perhaps the starch or the sugar was detrimental, but the fungus grows well on a starchy medium prepared according to Smith (6, p. 196), although not so well on media rich in sugar. It seems probable that neither the sugar nor the starch restricts the growth of the organism to the epidermis only, but this is done by the enzymes of the host.

**TAXONOMY OF THE FUNGUS**

The name "*Monilochaetes infuscans,*" meaning black bristly Monilia, given by Halsted to the soilstain fungus, remarkably describes the main features of the organism. However, Halsted failed to describe fully either the species or the genus. Saccardo (5) barely mentions the fungus. Neither Engler and Prantl (2) nor Clements (1) nor any other systematic writer on fungi record the genus Monilochaetes. The description given by Stevens (7, p. 597) is incomplete. It was probably taken from naturally infected material, where the chains of conidia are seldom, if ever, noticed, since they are partially broken off with the rubbed epidermis. The conidiophores in such material are often broken down or wanting. From the present studies it seems that the writer is warranted in retaining the names of both the genus and the species of Monilochaetes as used by Halsted. Harter (4), too, decided to retain this genus. The description from a pure culture follows.

*Monilochaetes infuscans* E. and H.

Spores borne in chains which readily break up; conidia hyaline to greenish, guttulate; conidiophores black, several septate; mycelium first hyaline, then darker with age. The submerged mycelium swells irregularly. Conidiophores, 100 to 300 by 3 to 7μ; conidia, 15 to 20 by 4 to 6μ. The fungus is a very slow grower on artificial media. Parasitic on the sweet-potato root, causing a brown, blotched disease of the epidermis.
Soilstain, or scurf, is a disease of the epidermis of the sweet-potato root. The disease occurs in every sweet-potato section, East and South, and is probably generally distributed. It is more abundant in the heavier soils, especially where manure is used as a fertilizer.

Soilstain reduces the market value of the mature roots. It reduces the average yield by attacking also the younger rootlets and stunting their development.

Soilstain is a disease of the underground parts of the plant. In storage the disease spreads by contact and is favored by moist, poorly ventilated houses.

The fungus *Monilochaetes infuscans* is difficult to culture, because it is a very slow grower and is readily overrun by associated saprophytes. The conidiophores of *M. infuscans* are distinct from the mycelium, the older growth of which is also dark. The conidia are borne in chains which readily break up when moistened or disturbed.

**LITERATURE CITED**

(1) **Clements, F. E.**

(2) **Engler, Adolf, and Prantl, K. A. E.**
1897-1900. Die natürlichen Pflanzenfamilien ... T. 1, Abt. 1, 1897; T. 1, Abt. 2**, 1900. Leipzig.

(3) **Halsted, B. D.**

(4) **Harter, L. L.**

(5) **Saccardo, P. A.**
1911. Sylloge Fungorum ... v. 20. Patavii.

(6) **Smith, Erwin F.**


(7) **Stevens, F. L.**

(8) **Taubenhaus, J. J.**
1914. Soil stain and pox, two little known diseases of the sweet potato. (Abstract.) In Phytopathology, v. 4, no. 6, p. 405.

(9) ——— and Manns, T. F.
PLATE LXXVI

Fig. 1.—Petri dish containing a pure culture of *Monilochaetes infuscans*.

Fig. 2.—a, Part of a conidiophore of *M. infuscans*, showing the unbroken chain of conidia; *b, d*, and *k*, various ways of the breaking up of the chains of conidia when disturbed or moistened; *c, e, f, g, h*, and *j*, spores collecting in pockets after the chains of conidia have broken up; *i*, bending in of the chain of conidia prior to breaking up into individual spores.
Soilstain, or Scurf, of Sweet Potato

PLATE LXXVI

Journal of Agricultural Research
Vol. V, No. 21
PLATE LXXVII

a, Part of a cross section of a sweet-potato root, showing the relationship of Monilochaetes infuscans to the epidermis of the host;
b, Germination of a fragment of mycelium of M. infuscans, showing the germ tube which is first produced and upon which conidia are borne;
c, d, e, f, g, h, i, and t, Different stages in the development of the spore and the chain of conidia;
o, j, k, and p, Protruding hyaline tube at the tip of the conidiophore on which are borne the conidia; this form of fruiting is not common;
l, n, and u, Differentiation of the coarser dark mycelium, and the finer hyaline to subhyaline hyphae;
u, Attachment of the conidiophore to the mycelium;
r, Conidiophore-bearing mycelium, being part of u;
m, q, s, v, x, y, and z, Different stages in the germination of the conidia of M. infuscans.