MORPHOLOGY AND TAXONOMY OF THE PECAN-SCAB FUNGUS, CLADOSPORIUM EFFUSUM (WINT.) COMB. NOV.

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INTRODUCTION

In the southeastern part of the United States the fungus hitherto known as *Fusidalium effusum* Wint. causes a widely prevalent and destructive disease, commonly called scab, on the wild and cultivated pecan (*Carya pecan* Brit.). The first recorded collection of the fungus was made by F. S. Earle, who collected affected leaves of the mockernut, *H. alba* (L.) Brit. (*Carya alba* (L.) K. Koch), near Cobden, Ill., October 1, 1882. This collection was sent to G. Winter, Berlin, Germany, who about three years later described (11) the fungus as *F. effusum*. In 1888 Langlois collected at St. Martinsville, La., leaves of the pecan parasitized by a fungus that was described and named *F. caryigenum* (6). This locality is well within the range of the present known distribution of the pecan-scab disease. Orton (9) considered *F. caryigenum* Ell. and Lang. identical with *F. effusum* Wint.

Although the fungus is common on the pecan in the southeastern part of the United States, it has been found only occasionally on other species of *Carya*. During the last three years the writer has made several collections of the fungus on *H. alba* near Thomasville, Ga., and one near Charleston, S. C. Two collections were made at Manhattan, Kans., on *H. cordiformis* (Wang.) Brit. (*C. amara* Nutt.). The fungus was also reported (3) on that host from Wisconsin. In 1926 Nolen (8) reported collecting the fungus in Florida on *H. aquatica* (Michx. f.) Brit.

THE FUNGUS

The fungus is strongly parasitic and invades only young or growing tissues. It attacks nuts (pl. 1, B), twigs, leaves (pl. 1, A), and catkins of the pecan, but it is known to attack only the leaves of other species of *Carya*. The exact method by which the germ tube enters the host has not been demonstrated. Under favorable con-

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3 Reference is made by number (italic) to "Literature cited," p. 186.

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(181)
ditions the incubation period may be as short as 4 to 5 days, but frequently lesions do not become noticeable until a period of 8 to 10 days has elapsed. The disease is rather superficial, extending only slightly below the epidermis. The affected tissues become black, hardened, and somewhat cracked, but show no tendency to decay unless they are later attacked by secondary invaders such as the pink-rot fungus (*Cephalothecium roseum* Cda.). On nut hulls, twigs, petioles, rachises, and leaf veins the fungus forms black stromata, which are raised somewhat above the infected host tissue.

![Diagram of sporulation and branching of the pecan-scab fungus.](image)

Fig. 1.—Method of sporulation and branching of the pecan-scab fungus. × about 540

The first conidiophores push out through the cuticle, but as the epidermis and the cuticle are destroyed by the anastomosing hyphae the later ones are produced directly upon the surfaces of the newly formed stromata.

The conidiophores are dark brown near the base but lighter toward the tips. They vary in length from 40 to 75 μ and may be either straight or flexuose and either simple or laterally branched. On the host tissues and under natural conditions the conidia regularly and constantly form in chains. (Pl. 1, C, and fig. 1.) The number of conidia in a chain varies from two to nine and probably averages four
A, Pecan leaves typically marked by the pecan-scab fungus. Most of the spots originated on the veins. B, Lesions on an immature pecan nut. The small spots originated from conidia produced on the larger central primary one. C, Chains of conidia of the pecan-scab fungus, photographed upon living host tissue, X 360. D, Reproduction of a drawing by Bonorden illustrating his conception of the method of sporulation of the genus Fusicladium (i., pl. 1, fig. 94). E, Parallel cultures of the pecan-scab fungus (a), and the peach-scab fungus (Cladosporium carpophilum Thüm. b), grown on Lima-bean agar for 34 days at a temperature of 24.5° C.
or five. Usually the chains originate at the tips of the conidiophores, but occasionally they develop laterally on the conidiophores at points immediately below septa or less frequently between them. The chains of conidia often branch in an indefinite and irregular manner. The conidia are formed acropetally. The first conidium that is formed on the tip of a sporogenous hypha soon gives rise, usually at its apex, to a papillalike projection. (Fig. 1.) The papilla first lengthens, then assumes a beadlike shape, and finally develops into a mature conidium. In the same way this newly formed conidium gives rise to a third, and in like manner a chain of several successive conidia may be produced. The chains branch by a mature conidium’s forming two or more papillae, each of which becomes the starting point of a short chain.

The conidia (fig. 2) are light brown. They vary considerably in both size and shape. In measurements of 200 the dimensions varied from 4.5 to 10 μ in width and from 10 to 28 μ in length. Their average size was 7 by 17 μ. They may be ovate to almost cylindrical, but most of them are either spindle shaped or clavate. All abscised conidia, except those that terminated their respective chains, have both basal and apical scars, showing that they had been attached at both ends. The newly formed conidia are one celled, but some become one or two septate upon germination.

METHODS OF DEMONSTRATING THE CATENULATE ARRANGE-
MENT OF CONIDIA

Conidia of the pecan-scab fungus are so easily pulled apart that the chains are broken up at once when they come in contact with a liquid. Therefore, the catenulate arrangement of the conidia can not be easily demonstrated by the usual method of preparing either temporary or permanent mounts. The breaking up of the conidial chains when coming in contact with a liquid is undoubtedly the principal reason why the true method of conidial production has been overlooked in the past and why the fungus has been classed as a Fusicladium. Conidia mounted in either water or other mounting fluids, no matter how carefully handled, seldom furnish more than mere suggestions that they are formed in chains. In such mounts about the only observable evidences of their arrangement in chains are (1) that an occasional conidium may be found with a bud or immature conidium attached to it and (2) that most conidia show both basal and apical scars.

The following method of studying the manner of conidial formation was found to be very satisfactory: A small section of host tissue, bearing an incipient scab infection, was cut from a living pecan leaf. It was found best to select an infection located on the rachis or some other part largely composed of vascular tissue. The excised host

![Fig. 2.—Conidia of the pecan-scab fungus. Note apical and basal scars on most conidia. (Drawn by the aid of a camera lucida)]
tissue was then sliced very thin with a hand sectioning outfit, and the sections were floated on a drop of water placed on a cover glass. Part of the water was allowed to evaporate, so that the sections would lie flat and adhere closely to the cover glass. The cover glass was then inverted over a culture ring with a drop of water in the bottom, and the joints were sealed with vaseline. Sufficient moisture to favor growth was absorbed by the host tissue and the mycelium. The specimens to be studied were then lying in a moist atmosphere and within focusing distance of a high-power objective. After exposure to a temperature of 24° to 26.5° C. for 8 to 12 hours, chains of conidia were frequently formed from the edges of the sections and in a plane parallel to the cover glass.

The technic just described permitted observation of the progress of sporulation from hour to hour and eliminated the necessity of moving the conidia from their original position during the course of the study. Cultures made by this method will remain for several days in condition for observation. Sections of living overwintered stromata from twigs or hulls will give similar results.

The catenulate arrangement of the conidia can also be demonstrated by carefully forming a crease across a new leaf infection and with the medium-power objective examining the conidia as they project beyond the leaf tissues. To get the best results from this method of observation, new leaves bearing recent infections should be collected and placed in a moist chamber for a period of 12 to 18 hours prior to examination. The chains will then stand out distinctly. Dry mounts will also show the conidia in chains, but in a manner less satisfactory for study. In 1926 the writer (4) called attention to the catenulate arrangement of the conidia and pointed out that this character precludes the inclusion of the fungus in the form genus Fusicladium.

The genus Fusicladium was founded by Bonorden with the species virescens as the type. (Pl. 1, D.) A translation of his description of the genus is as follows: "Unbranched septate hyphae, bearing at their apices, which sometimes have two projections, one or two spindle-shaped simple spores" (1, p. 80, pl. 4, fig. 94).

Engler and Prantl (7) list the genus Fusicladium in the Dematiaceae-didymosporae under the subdivision "Conidia not formed in chains." Saccardo (10, p. 345) also catalogues the genus Fusicladium in the Dematiaceae-didymosporae and under the subdivision "Conidia not catenulate—merely acrogenous."

COMPARISON WITH THE APPLE-SCAB AND PEACH-SCAB FUNGI

Fusicladium dendriticum (Wal.) Fcl., the conidial stage of Venturia inaequalis, has probably been studied more closely both in this country and in Europe than any other member of this form genus. In a description of this fungus Duggar (5) describes its method of sporulation as follows:

These conidiophores arise from the subcuticular or subepidermal mycelium * * * and a spore is soon developed at the tip of each * * *. However, when this spore is abscised, the conidiophore grows further, leaving a slight knee or other evidence indicating the point where the previous spore was borne. In this manner many successive conidia may be produced, and the conidiophore therefore becomes flexuous and irregular.
This description seems to conform quite closely to the general conception of the method by which the species of Fusicaladium produce their spores.

Since the resemblance in morphological and cultural characters between the pecan-scab pathogene and the peach-scab fungus (Cladosporium carpophilum Thüm.) is much greater than between the former and the apple-scab fungus (Fusicaladium dendriticum), it seemed to the writer that there might be a closer affinity between the pecan-scab and the peach-scab fungi than between the pecan-scab and the apple-scab fungi. Therefore, as a supplement to this study, comparative studies of the cultural and morphological characters of all three forms were made.

The results of these studies indicate that the pecan-scab organism possesses certain cultural and morphological characters in common with the peach-scab fungus. Both develop in artificial media very slowly at first, monosporous cultures requiring two or three weeks before becoming large enough to be seen macroscopically. Both produce a black stromatoid growth which attains a maximum surface diameter of 10 to 15 mm. in 8 to 10 weeks. Upon artificial media and living host tissues both produce, acropetally, catenulate conidia that are much alike in shape, color, and method of germination. Both produce a superficial growth upon infected host tissues, and both pass the winter as stromata or masses of pseudoparenchymatous tissue. The only essential cultural difference noted was that the pecan-scab organism produces conidia sparsely in culture, whereas young cultures of the peach pathogene produce them in abundance. (Pl. I, E.)

Many specimens of the conidial stage of the apple-scab fungus on living apple leaves were examined. All methods were employed that had proved successful in studying the conidial production of the pecan-scab fungus, but in no certain case was the apple-scab fungus observed to be producing its conidia in chains. On the other hand, on living host tissues it regularly produces its conidia singly on short mostly one-celled sporophores in accordance with the usual conception of the genus Fusicaladium.

These two forms of Fusicaladium and Cladosporium were selected for comparison with the pecan fungus on account of their generally accepted validity, accessibility, and adaptability as types for study. Furthermore, Clinton (2) thinks it possible that F. virescens Bon., the type species of the genus Fusicaladium, may be identical with either the conidial stage of the apple-scab or the pear-scab fungus. The evidence seems to suggest that it is more probably identical with the apple-scab fungus, since Bonorden gives the apple as the host for his fungus.

The results of those comparative studies indicate that the pecan-scab organism possesses certain cultural and morphological characteristics in common with some members of the genus Cladosporium. Its similarity with C. carpophilum is so striking that it suggests the probability of close relationship and seems sufficient to warrant its transfer from the form genus Fusicaladium to the form genus Cladosporium.
EMENDED DESCRIPTION

The reclassification of the fungus as a member of the form genus Cladosporium is proposed, with, of course, the retention of Winter's specific name. It seems desirable to include in the description of the fungus the hitherto unpublished facts concerning its morphology. The following emended description of the species is therefore given:


Mycelium olive brown, subepidermal at first, later forming pseudoparenchyma of more or less irregular cells on twigs, petioles, and fruits. Stromata formed late in summer remaining in semidormant condition during the winter and sporulating the following spring; conidiophores simple or branched, 1 to 4 septate, dark brown, 40 to 75 μ long. Conidia fusoid to ovate clávate, light olive brown, continuous, occasionally becoming 1 to 2 septate, 4.5 to 10 μ by 10 to 28 μ, catenulate, forming acropetally; chains frequently branched.

Parasitic on nut hulls, twigs, leaves, catkins of the pecan (Hicoria pecan), and on leaves of some other species of the genus Hicoria in the central and south-eastern parts of the United States.

In artificial culture the fungus grows very slowly. Ten to fifteen days are often required for growth originating from a single conidium to become large enough to be seen macroscopically. When fully developed, which requires from two to three months, the colonies are lens shaped to irregular. The submerged portion is dark brown to black. The exposed part of the stromatoid mass is covered with brown to gray aerial hyphae. Conidia are produced but sparingly in artificial cultures.

The fungus first forms noncolored restricted areas on the host. Later the spots appear black, as the mycelium forms pseudoparenchyma or stromata involving or rupturing the epidermis.

SUMMARY

The pecan-scab organism has for many years been accepted as a species of the form genus Fusicladium. This genus, according to the description by Bonorden, its author, should include only those forms of the Dematiaceae forming one-celled conidia singly or in pairs on short conidiophores.

The result of the present study demonstrates that the pecan-scab fungus forms its conidia in either simple or branched chains. The number of conidia in a chain seems to vary from two to nine, and probably averages four or five.

Simple methods of demonstrating the catenulate arrangement of the conidia are described.

The reclassification of the fungus as a member of the form genus Cladosporium with the name C. effusum, comb. nov. is proposed.

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