FUNDAMENTALS FOR TAXONOMIC STUDIES OF FUSARIUM[1]

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INTRODUCTION

There has been a long-felt need for a general conference of all workers on the Fusarium problem in order that a uniform taxonomy may be formulated upon which future work can be based. The various workers have always been fundamentally in reasonably close agreement regarding the principles of Fusarium classification, but there has been a number of points which were not clearly understood, possibly because the investigators have not been sufficiently in contact with each other. Variations in the methods employed in different laboratories have complicated the problem of species identification. The fact that the fungi vary according to the environment, age, and source of culture and the failure of different workers to understand one another has, it is believed, largely accounted for the differences arising from Fusarium studies.

Recent investigations on the banana-wilt problem conducted by the United Fruit Co. in Central America showed the immediate necessity of a general conference on the Fusarium problem. Because of the large number of related Fusaria encountered in a study of the banana-wilt-producing organism on banana plantations, it was deemed advisable to complete the fungous investigations with a final study in Europe or in the United States. The proposed studies of the United Fruit Co. were discussed at the meeting of scientific societies in Cincinnati, in December, 1923, and through Dr. W. A. Orton a plan for an American conference on Fusarium was proposed. The idea involved the United Fruit Co.'s bringing Dr. H. W. Wollenweber over from Germany, and Dr. O. A. Reinking from Central America. The United States workers included Dr. C. D. Sherbakoff, of the University of Tennessee, Miss Helen Johann and Mrs. Alice A. Bailey, representing, respectively, the Offices of Cereal Investigations, of Cotton, Truck, and Forage Crop Disease Investigations, and of Pathological collections of the United States Department of Agriculture, in a joint study of Fusarium classification. The United Fruit Co., through its director of agricultural research, Dr. John R. Johnston, adopted this liberal policy in supporting the scientific work to a greater extent than their purely economic interests required. It was agreed, on the invitation of Dr. L. R. Jones, to hold the conference at the University of Wisconsin, in Madison.

The purpose of the conference was to give an opportunity to cooperate in a personal way, to compare cultures assembled from all possible sources, and in this manner to clear up the somewhat tangled taxonomy of this difficult genus. All the important European cultures, those being studied at present in the United States, and the collections made from the tropics, primarily from Central America, were assembled at the meeting for special study and comparison. The work of the conference covered, in so far as possible, the study, comparison, and identification of the specimens and cultures of the fungi then available. The main studies were made on the tropical collection, since it was agreed, because of the part taken by the

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United Fruit Co., that the conference should facilitate, in the best way possible, a satisfactory definition of the numerous species found on banana plantations. The studies made of the entire collection embodied species from all sections of the genus Fusarium, including important border-line strains, thereby making it possible to arrive at a uniform taxonomy of the group. It is believed that the main points of difference have been agreed upon and that the present paper will present a clearer understanding of the Fusarium problem from the standpoint of the identification of species.

Material of each species studied and identified at the conference will be deposited in the pathological collections herbarium of the Bureau of Plant Industry, United States Department of Agriculture, for permanent preservation. The cultures will be prepared in the manner most satisfactory for the preservation of herbarium material. Pure cultures of each of the species studied and identified will also be placed in the bureau. These cultures will have substantially the status of type specimens.

CRITERIA OF THE NORM

Only a résumé of the criteria of the norm will be here considered, since a complete discussion of the subject has appeared in former publications (*5*, *9*).[5] The normal condition of Fusaria from the standpoint of determination may be present in nature, but generally it must be produced by growing the fungi under pure culture conditions. A few Fusaria such as *F. dimerum* Penz., *F. scirpi* Lamb. et Fautr., *F. culmorum* (W. G. Sm.) Sacc., and some others may be determined directly from the fungus growing under natural conditions without resorting to pure cultures. Other Fusaria, which appear primarily in a microconidial stage under natural conditions and produce only a few sickle-shaped spores, are more difficult to identify. For these the so-called normal growth must, at first, be produced. It is, therefore, necessary to make a careful study from pure culture in order accurately to identify these organisms. Generally, macroconidia are regarded as the normal spore type. In certain groups, however, the microconidia may have definite characters, such as a pearlike shape or a formation in chains, which aid in the determination of the section (Sporotrichiella, Arthrosporiella) and, in exceptional cases, may even lead to the identification of species (*F. poae* (Peck) Wr., *F. moniliforme* Sheld., *F. decemcellulare* Brick.).

Other normal reproductive stages, such as chlamydospores, by their presence or absence indicate the border of certain groups (Elegans, Lateritium). Sclerotia may be characteristic for groups (Lateritium) and even for a number of species (*F. sclerotium* Wr.). Color of the conidia and color of the aerial mycelium and stroma are further reliable characters for taxonomy. Minor characters such as mycelium, hyphae with specialized cells, coremia-like aggregations of hyphae, and aromatic odors may also be of some importance for differentiation. In opposition to the norm there are abnormal features which might be valuable to mention in the diagnosis. Not so much stress, however, is placed on degenerated conditions in the life cycle of Fusaria.

[5] Reference is made by number (italic) to "Literature cited," p. 843.

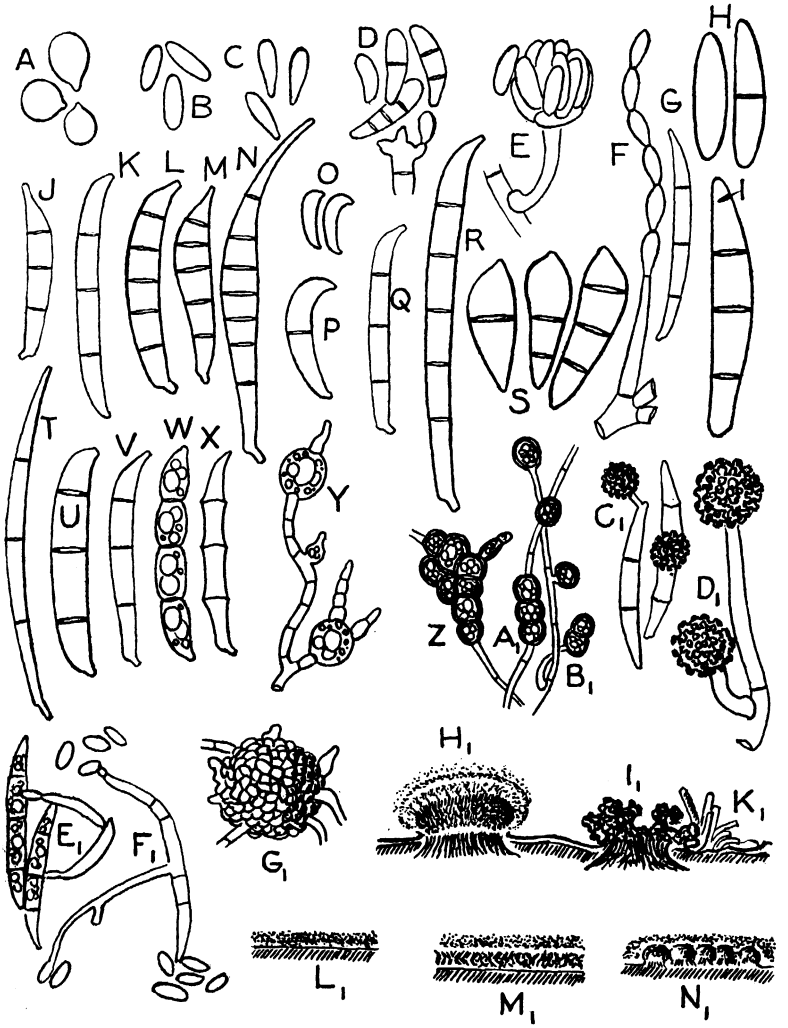

FIG. 1.—Stages in the life cycle of Fusaria:
A–F, H and S, microconidia.
I–R, T–X, macroconidia.
Y, Swellings of hyphae.
Z, A_1–D_1, Chlamydospores.
E_1–F_1, Conidial propagation from conidia.
G_1, Sclerotium.
H_1, Sporodochium.
I_1, Sclerotia in clusters on an erumpent base.
K_1, Columns formed by conidia borne in chains.
L_1–N_1, Pionnotes covering either the medium directly (L_1), or a mycelial sheet (M_1), or numerous associated sporodochia (N_1) formed on the substratum.

Examples: *Fusarium poae* (Peck) Wr. (A, J), *F. orthoceras* App. et Wr. (B, E, K, A_1, B_1), *F. moniliforme* Sheld. (C, F, G, G_1), *F. chenopodinum* (Thüm.) Sacc. (D, M, N, Z), *F. argillaceum* (Fr.) Sacc. (H, I, C_1, D_1), *F. subcarneum* Crouan (L), *F. flavum* (Fr.) Wr. (O), *F. dimerum* Penz. (P), *F. salicis* Fuck. (Q), *F. sarcochroum* (Desm.) Sacc. (R, S), *F. viticola* Thüm. (T), *F. solani* (Mart. pr. p.) App. et Wr. (U), *F. vasinfectum* Atk. (V, normal, W, swollen, X, dried spore), *F. tricinctum* (Cda.) Sacc. with swellings of hyphae (y), *F. macroxysporum* Lindf. with pionnotal propagation of macroconidia (E_1) and development of microconidia (F_1).

For a proper understanding of the terms (*8*) used for normal forms of reproductive stages and mycelium of Fusaria the characters considered of primary importance are enumerated below.

I. Normal reproductive stages

1. *Microconidia:* 0–(0–3)–septate, globose-pearshaped as in *F. poae* (Peck) Wr. (fig. 1A); ellipsoidal as in *F. orthoceras* App. et Wr. (fig. 1, B); ovoid-fusoid as in *F. moniliforme* Sheld. (fig. 1, C); comma-shaped as in *F. chenopodinum* (Thüm.) Sacc. (fig. 1, D). They may be found scattered (fig. 1, A–D), in false heads (fig. 1, E), or in chains (fig. 1, F) and may form sporodochia and pionnotes.

2. *Macroconidia*: 0-pluriseptate, dorsiventral, fusoid to sickle-shaped, apedicellate and pedicellate, scattered, sporodochial and pionnotal.

   a. Septation types:
      0–septate, *F. flavum* (Fr.) Wr. (fig. 1,O);
      1–septate, *F. dimerum* Penz. (fig. 1, P);
      3–septate, apedicellate, *F. betae* (Desm.) Sacc. (fig. 1, K);
      3–septate, pedicellate, *F. poae* (Peck) Wr. and (fig. 1, J);
      5–septate, *F. chenopodinum* (Thüm.) Sacc. and (fig. 1, M);
      5–7–septate, *F. chenopodinum* (Thüm.) Sacc. and (fig. 1, N);
      9–septate, *F. decemcellulare* Brick.

   b. Sporulation types: Scattered; in false heads; pionnotes, continuous, gelatinous, slimy, (*1*) formed on the naked surface of the substratum (fig. 1, L_1) as in section Eupionnotes, species of section Roseum, Gibbosum, Elegans and Discolor, or (*2*) on a mycelial sheet as in *F. avenaceum* (Fr.) Sacc. (fig. 1, M_1) or (*3*) composed of an aggregation of sporodochia as in *F. martii* App. et Wr. (fig. 1, N_1); sporodochia, (*1*) tubercularialike (fig. 1, H_1) found in the majority of species of all sections except Ventricosum and some species of Elegans and Eupionnotes (*2*) in columns representing a chainlike development, as in *F. stilboides* Wr. (fig. 1, K_1).

   c. Shape: Fusoid-lanceolate, slightly curved, mostly apedicellate, *F. argillaceum* (Fr.) Sacc. (fig. 1, I); slightly sickle-shaped, apedicellate, *F. betae* (Desm.) Sacc. (fig. 1, K); sickle-shaped, pedicellate, most of the species; strongly dorsiventral, *F. scirpi* Lamb. et Fautr. and *F. chenopodinum* (Thüm.) Sacc. (fig. 1, N); terminal cell suddenly constricted, *F. culmorum* (W. G. Sm.) Sacc. and *F. chenopodinum* (Thüm.) Sacc. (fig. 1, M); terminal cell whiplike, much elongated *F. scirpi* Lamb. et Fautr. and *F. chenopodinum* (Thüm.) Sacc. (fig. 1, N); curvature within the limits of conical sections as elliptic (fig. 1, M), parabolic and hyperbolic (fig. 1, N). The curvature is mainly determined from the dorsal and ventral sides of spores, in side view, within the septation region.

3. *Chlamydospores:* Terminal (fig. 1, B_1, D_1), intercalary (fig. 1, A_1), single, in chains, in clusters, mycelial (fig. 1, Z to B_1), conidial (fig. 1, C_1).

   a. Terminal: In sections Elegans, Martiella, Ventricosum; unicellular, *F. argillaceum* (Fr.) Sacc. (fig. 1,N D_1); 0–1-septate, sections Martiella and Elegans (fig. 1, B_1). Most fungi forming terminal spores may also develop intercalary spores. In section Ventricosum no intercalary spores are produced.

   b. Intercalary: Mostly 0–1-septate (fig. 1, A_1) in sections Elegans, Martiella, Discolor, Gibbosum, and Eupionnotes (subsection Chlamydospora). Chains and clusters (fig. 1, Z) may also occur in most of these sections.

4. *Sclerotia:* Plectenchymatic structures, general appearance similar to perithecia of Gibberella, but with uniform structure throughout. Globose or rugose, single or in cauliflowerlike clusters (fig. 1, G_1). Color, blue in sections Roseum, Gibbosum, Lateritium, Discolor, Elegans, and Martiella; brownish to dark brown in Arthrosporiella (*F. diversisporum* Sherb.), Gibbosum, and some species of section Discolor.

II. Color characters

1. *Color of conidia:* Brownish white to golden yellow in section Martiella; brownish white to pale orange in section Elegans, Discolor, Gibbosum, and Arthrosporiella; orange in section Roseum Lateritium, Eupionnotes and Arachonites. The color of conidia is sufficiently constant to be a reliable character for some groups.
2. *Color of aerial mycelium:* White, rose to yellow and blue, mostly representing a diffused color of the stroma. Changes in color of mycelium due to the reaction of the substratum is substantially the same as that discussed under color of stroma.
3. *Color of stroma:* Brownish white, carmine, yellow, and blue. The acid modification is especially well developed on sterilized rice and may aid in the identification of Fusarium groups. This acid modification differs in some sections for it is golden yellow in most of the species in section Discolor, Saubinetii, Roseum, Sporotrichiella, and in some of Gibbosum; rose to vine red in many species of section Elegans; and rose to brown color, with a tendency toward diffusing into rice, in section Martiella. The basic color modification is mostly blue or violet. In general, all of these fungi produce on rice an acid color modification that may change gradually with age into an alkaline modification. This color change can be produced at once by the addition of sufficient alkali to a well-developed culture of the fungus on rice. Other characteristic colors produced on sterilized potato tubers are carmine red by species of section Discolor, Roseum, Sporotrichiella, and some of Gibbosum, and citric or sulphuric yellow in Necsiola subsection of Discolor. These colors are of the basic modification and consequently are not turned blue by the addition of alkali. The carmine red turns yellow with an addition of acid. No color contrast is observed in sections such as Eupionnotes, Arachnites, and Ventricosum. The stroma and aerial mycelium of these fungi have the color shades of their conidia. The color of sclerotia and sclerotial stroma is blue in some and brown in other groups, as discussed under sclerotia.

III. Minor characters

1. *Hyphae with swollen cells:* Not true chlamydospores (fig. 1 Y) as in *F. flocciferum* Cda. and *F. tricinctum* (Cda.) Sacc.
2. *Aerial mycelium:* Loose, dense, jellylike, cottony, radiate, zonate.
3. *Immersed mycelium*: Slimy or leathery sheet (stroma), that may or may not have a plectenchymic base. Section Eupionnotes.
4. *Coremialike aggregations of hyphae.* Aggregations of anastomosed hyphae as in Eupionnotes and Ventricosum. True coremia so far were not observed.
5. *Aromatic odor:* Somewhat similar to lilac odor, produced by a number of species of section Elegans such as *F. oxysporum* Schlecht., *F. hyperoxysporum* Wr., *F. zonatum* (Sherb. s. var.) Wr., *F. vasinfectum* Atk., and *F. cubense* Erw. F. Sm. The last three species have the strongest odor, especially when grown on rice.

IV. Abnormal characters

1. *Spore:* Exceptional size, irregularities in shape of conidia, swollen cells in germinating spores (fig. 1, W) and constricted cells in dry conidia (fig. 1, X). These abnormal characters, although frequently present, are not taken into consideration for taxonomic purposes and have been more fully discussed elsewhere (*1*).

2. *Mycelium:* With the exception of Eupionnotes, in which immersed growth of the mycelium predominates even under normal and favorable spore production, changes to an immersed gelatinous growth in general indicate degeneration and self-digestion accompanied by abnormal spore production or even sterility. This condition may be changed into the norm by transferring to various media or by selection of virulent aerial colonies from new agar plates. Fortunately the number of Fusaria showing a tendency to degenerate seems to be small. This tendency is notable in *Fusarium nivale* (Fr.) Sacc., *F. anthophilum* (A. Br.) Wr., *F. orthoceras* App. et Wr., and *F. flocciferum* Cda. The latter two fungi if inoculated into living potato tubers, thoroughly disinfected with formaldehyde, regain their normal behavior when reisolated and retransferred to sterilized media. In some cases, agar media too rich in sugar or too alkaline or acid in reaction favor degeneration. Conditions, however, that favor normal conidial production generally warrant longevity and sufficient constancy. On the same medium mycelium transfers often give only a sterile stroma, while a transfer of macroconidia increases the tendency to reproduce this stage. These facts if not fully understood may make the proper identification of certain species doubtful. They show the necessity of improving cultural methods.

Brown and Horne (*3*) in their studies of the genus Fusarium have given interesting details on the modifying effect of transfers from various parts of a given fungus. These authors have stated that the rate of spread of certain colonies fell off after a time and was reduced (staling), while other colonies developed into normal sporodochia or pionnotes with small and low septate or long and high septate conidia. Furthermore, "saltants" showing sectorial effects of some strains have been produced in Fusaria derived from six different isolations from apple. In the preliminary studies this wide range of variability was considered to be connected with one and the same fungus, *F. blackmani* Brown et Horne.

This variability of the mycelium and spore character has been found to occur with various fungi. Notable among these are two closely related Fusaria described as *F. anguioides* Sherb. and *F. anguioides* var. caudatum Sherb. (*5*). These two organisms are closely related to *F. anthophilum* (A. Br.) Wr. isolated from apple fruit in England. The abnormal variations found in these cases, though great, were not mentioned in the diagnosis of the Fusaria because normal characters were regarded as sufficient for determination.

PRODUCTION OF THE NORM

Cultural conditions which will produce good mycelial growth are not necessarily those most favorable for the production of normal spores. In the study of Fusarium it has been found necessary to use a variety of media for the production of the various normal mycelial and reproductive stages. The best media for these purposes at present available are the ordinary ones used in plant pathology investigations. A combination of a number of vegetable substances may prove valuable in some cases, but, so far, sufficient work has not been done to justify recommending such a medium. Because the same vegetable under different conditions varies in its chemical composition, it would be highly desirable to produce a satisfactory synthetic medium. It is hoped that a synthetic nutrient may sometime be found which will render it possible to control the production of spore bodies or sclerotia at will. Until some such new media are produced, vegetable media will be found to be fairly satisfactory for taxonomic purposes.

No one culture medium is at present used which will produce optimum development of all phases of fungus growth; hence certain media have been selected which proved most satisfactory for the best production of conidia, and other media for the production of sclerotia, mycelium, chlamydospores, and other characters. It must be understood, however, that not all species will react in exactly the same way, and therefore a medium which produces normal conidia in most species may need to be supplanted by another in the case of other species. The media used at the conference are given in Table I.

TABLE I.—*Culture media showing types of growth readily produced on each.*[a]

Media	Conidia	Chlamydospores	Sclerotia	Mycelium	Color
Potato tuber cylinders (no water added)	+	+	+	+	+(basic)
Oatmeal agar (Sherbakoff (5))	+		+		+(basic)
Potato agar+2 per cent dextrose (200 gm. to 1,000 c. c.)	+	+	+		
Potato agar+5 per cent dextrose (200 gm. to 1,000 c. c.)	+		+	+	+(basic)
Rice (2 gm. to 6 c. c. water)	+		+		+(acid)
Melilotus stems (mature stems+4 c. c. water)	+	+	+		Color of spores
Lupinus stems (mature stems+4 c. c. water)	+		+		Color of spores
Alnus (2 to 3 year twigs+4 c. c. water)	+		+		Color of spores

[a] All agar media contains 2 per cent agar. All media are autoclaved for 45 minutes at 10 pounds pressure except rice, which is steamed for one hour on three successive days. When necessary to use young Melilotus stems, 4 c. c. of a 0.5 per cent KOH solution should be used in place of water to neutralize the acidity of the stems.

In general, the use of several vegetable media, such as those mentioned in the table, will result in the production in good condition of the various characteristics of the fungus. In some cases special methods must be employed for the production of certain phases. The addition of acid to the standard potato agar greatly stimulates an abundant porduction of normal spores in such species as the Fusarium stage of *Gibberella saubinetii* (Mont.) Sacc. Substances poor in food value favor the production of chlamydospores. In species which produce chlamydospores only rarely, as *F. aurantiacium* (Lk.) Sacc., chlamydospore development may be brought about by growing in sterile tap water. The reaction of the medium is important from the standpoint of color production and, in some cases, greatly influences growth of mycelium and abundance of spore production.

In transferring, it must be borne in mind that the type of inoculum influences the resultant growth. Continuous transfer of one type of inoculum tends to production of that type of growth. Repeated transfer of mycelium or chlamydospores tends to good development of mycelium and sclerotia in those species which have sclerotia. For production of abundant spores, transfers should be made from sporodochia or pionnotes. When sporodochia are lacking and macrospores are not numerous, the chance of transferring mycelium may be eliminated by making dilutions in tubes of sterile water and transferring a loop full of the dilution to the culture medium, or by using the plate dilution method. The latter method affords an opportunity to select colonies showing the greatest tendency toward spore production.

Environmental factors other than the medium which should be taken into consideration are temperature, humidity, and light. There are indications, in some species at least, that temperature has an appreciable effect upon the morphology of the conidia as well as upon the rate of growth of mycelium (*4*). Perhaps to temperature may also be ascribed part of the effect on color intensity usually attributed to light. Humidity affects the nature of the culture, as is evidenced by the increased production of chlamydospores in some species and the production of swollen conidia in excessively moist media. The fact that these environmental factors have been given very little consideration in identification of Fusaria may be responsible for some of the difficulties encountered in various countries where taxonomic work is done.

IDENTIFICATION

If we realize the fact that tubercular sporodochia with normal and uniform conidia occur in the majority of Fusaria that can be easily grown in pure culture, there will be no difficulty in judging the normal stages and, consequently, in identifying most of these fungi. For the remaining forms more detailed studies will have to be conducted in order to produce or prove the absence of particular stages such as sporodochia, pionnotes, chlamydospores, and sclerotia. It should be stated also that even conidia normal in appearance often differ greatly in their size and shape according to where they are produced, whether on mycelium' over a wet surface or in a definite sporodochium. In a typical pionnotes long conidia may be produced, and in sporodochia they may be considerably shorter, as in *F. vasinfectum* Atk., *F. cubense* Erw. F. Sm., *F. lycopersici* (Sacc.) Wr., and others. Differences in size and shape may also appear when the fungus is grown on

various types of media. In section Roseum longer and slenderer conidia are produced on rice and oatmeal agar than on other media more favorable to sporodochial development. Because of these differences, it is necessary to pay particular attention to the average size of different types as grown upon different media and under different conditions. A comparison must be made only of conidia produced under comparable conditions and between comparable sporulation types.

Often the identification is difficult because certain species persistently produce only a microconidial stage. In such instances some special methods must be employed to induce the fungus to develop macroconidia. For instance, in the case of *F. chenopodinum* (Thum.) Sacc. only the comma-shaped spore (fig. I, D) may be observed for a long time. However, by repeated transfers of occasionally found macroconidia, finally normal macroconidia can be obtained in abundance. These conidia enable us to identify the fungus with ease. It is important to emphasize that, in this species as in some others, often an intermediate type of macroconidia is produced when the fungus is in a semimycelial stage of growth and when sporodochia are underdeveloped. These conidia in *F. chenopodinum* (Thum.) Sacc. can easily be taken for those of *F. sambucinum* Fuck. Generally the microconidia in themselves do not represent definite enough characters to be used for identification.

In those doubtful cases where normal macroconidia are not readily produced the presence of chlamydospores may be of extreme importance for determining the group. The presence or absence of chlamydospores makes it possible to separate species of section Elegans with terminal chlamydospores from section Lateritium with no chlamydospores, even though their macroconidia may be similar when grown under certain cultural conditions.

The presence of ascigerous stages in some of the sections is of additional help in the identification of the imperfect or conidial forms (*9, 11*). A number of ascomycetes (Nectria, Calonectria, Hypomyces, Gibberella) have been grown from the ascospores in pure culture and developed the conidial stage, thus showing the relationship. In other cases cultures of Fusaria collected from nature have developed perithecia.

Color characters on various media rich in carbohydrates afford a fairly reliable means of placing the fungi into sections. The color of conidia and stroma especially represent an important complex for identification.

The ordinary procedure in determining Fusaria is to illustrate and measure normal spores and a few exceptions that show the variability and changes with increasing age. The standard magnification used for the drawings is 1–1000 for the spores and 1–500 for parts of sporodochia showing conidiophores and formation of spores. Smaller magnifications may be used for special purposes, such as groups of sporodochia, sclerotia, and stroma erumpent. For a short study water mounts are preferable. In order to prevent moisture from escaping during the procedure of drawing, the edges of the cover glass may be waxed. Another method (*7*) of preparing slides, which has the advantage of placing all the spores in one plane and holding them in place, is to make the mount on a very thin (0.5 mm.) sheet of agar placed on the slide. These agar sheets can readily be prepared by pouring clear agar between glass slides set the required distance apart. This method is very convenient for photographic purposes.

CLASSIFICATION OF THE FORM-GENUS FUSARIUM

The form-genus Fusarium includes all hyphomycetes and conidial stages of ascomycetes that have no black or pure gray color either in mycelium or in conidia and that have macroconidia that are acrogenous, typically septate, sickle-shaped, and not round at the ends. Microconidia, chlamydospores, and sclerotia may be present. Some Fusaria have been proved to be conidial stages of certain Hypocreaceae, such as Nectria, Hypomyces, Gibberella, and Calonectria. The fungi of the form-genus Cylindrocarpon, formerly considered as Fusaria, have Nectrias and certain Hypomyces (*8*) as perfect stages. Some of the species of Ramulara or similar fungi as Septomyxa also formerly placed under Fusarium, have as their perfect stage Neonectria (*10, 11*) and Mycosphaerella (*11*). The fungi parasitic on scale insects and possessing sickle-shaped to fusoid conidia are referred to the genus Microcera, which is said to be the conidial stage of Sphaerostilbe.

GROUPING OF FUSARIA IN SECTIONS

Many Fusaria readily fall into separate groups possessing similar characters. These groups are called sections, which, on the basis of their apparent

relationship, especially when their perfect stages are considered, are arranged as follows: 1, Eupionnotes Wr.; 2, Arachnites Wr.; 3, Sporotrichiella Wr.; 4, Camptospora Wr.; 5, Arthrosporiella Sherb.; 6, Gibbosum Wr.; 7, Roseum Wr.; 8, Liseola n. n.[6]; 9, Lateritium Wr.; 10, Discolor Wr.; 11, Spicarioides N.comb.[7]; 12, Saubinetii Wr.; 13, Elegans Wr.; 14, Martiella Wr. (sensu extenos)[8]; and 15, Ventricosum Wr.

KEY TO THE SECTIONS OF FUSARIUM

With the exception of section Camptospora (*10*), which needs further study, all of the species are arranged in the following key to the sections:

a. Microconidia on aerial mycelium usually present and dominately 0-septate, ovoid, fusoid, reniform, or pearshaped.
  b. 0-septate conida pearshaped. Macroconidia when normal are in shape intermediate between those of the sections Elegans and Roseum, though more curved than either; substratum rose-colored, intercalary chlamydospores, or similar structures may be present. Sec. 3, *Sporotrichiella*.
  bb. 0-septate not pearshaped.
    c. 0-septate conidia in chains.
      d. Conidial walls thin. Microconidia mostly in chains, fusoid-ovoid; macroconidia in form and color similar to those of sec. Lateritium; no chlamydospores; substratum vinaceous-violet; some of the species are connected with Gibberellas of sec. Lisea (Sacc.) Wr.....Sec. 8, *Liseola* n. n.
      dd. Conidial walls thick or highly refractable. Macroconidia pluriseptate, in shape resembling those of the sec. Discolor.....Sec. 11, *Spicarioides* n. comb.
    cc. 0-septate conidia not in chains.
      d. Conidial walls thin. Macroconidia attenuate at the top ends, pedicellate; terminal and intercalary chlamydospores present; color of conidia brownish to salmon; no blue or green color in conidia even as a diffusion from stroma; stroma on artificial media principally vinaceous to lilac.....Sec. 13, *Elegans*.
      dd. Conidial walls relatively thick. Macroconidia somewhat truncate or rounded at the top end, or at least not distinctly attenuate, some times slightly constricted at the tip ends; terminal and intercalary chlamydospores present; color of conidia brown-white to golden brown with occurrence of green to green-blue as diffusion from stroma.....Sec. 14, *Martiella*.
aa. Microconidia on aerial mycelium usually absent or 0-3 or more septate, reniform, comma, spindle, to sickleshaped.
  b. Macroconidia apedicellate. Color type, orange to light salmon.
    c. Typical pionnotes always present; comparatively slow-growing fungi.....Sec. 1, *Eupionnotes*.
    cc. Typical pionnotes absent; comparatively fast-growing fungi.....Sec. 2, *Arachnites*.
  bb. Macroconidia subpedicellate to pedicellate.
    c. Terminal chlamydospores present; intercalary chlamydospores absent; no true sporodochia; macroconidia wedge-shaped to slightly sickle-shaped, not constricted at the top. Sec. 15, *Ventricosum*.

[6] Liseola nn. (Syn. Constrictum Wr. pro parte subs. Elegantis; Moniliforme Sherb.*b*); Microconidiis plus minusve in catenulis, dispositis, fusoideis-ovoideis, macroconidiis forma et colore sectionis Lateritii, liberis, in sporodochiis, in pionnote; chlamydosporis nullis; stromaet violaceo. Status conidicus Gibberellarum sect. Liseae (Sacc.)

[7] Wr. Spicariodes (Wr. subsect.) n. comb. (Syn. subsect Spicarioides sectionis Discoloris Wr.) Microconidiis sporodochialibus pluriseptatis forma specierum sectionis Discoloris. Chlamydosporis nullis Stromate carmineo.

[8] *Martiella* Wr. (Sensu extenso sectionis Martiellam Wr. et Pseudomartiellam Wr. includendo). Macroconidiis dorsiventralibus fusoideofalcatis, apice rostrato truncato vel rotundato, basi plus minusve subpedicellata, in sporodochiis et pionnote sordide albo, ochroleuco vel aureo; stromate aerugineo fere nigrescenti, chlamydosporis terminalibus, intercalaribus, singulis, binis, catenulatis vel acervalibus. Status conidicus Hypomycetum sect. Pseudomartiellae.

cc. Terminal chlamydospores absent.
d. Intercalary chlamydospores present.
e. Sporodochia typically absent. Conidia, when free-borne on aerial mycelium, spindle-shaped. Macroconidia gradually attenuate, generally lanceolate, apedicellate; but also sickleshaped and pedicellate; color intermediate between that of Roseum and Gibbosum sections, sclerotia may be present---Sec. 5, *Arthrosporiella.*
ee. Sporodochia typically present.
f. Macroconidia with top ends much attenuated; stroma typically brown,[9] sometimes carmine[10]---Sec. 6, *Gibbosum.*
ff. Macroconidia with top ends somewhat truncate; conidia ochreous to salmon; stroma Roseum-like; blue sclerotia may be present---Sec. 10, *Discolor.*
dd. Intercalary chlamydospores absent.
e. Top ends of macroconidia gradually attenuate; when free-borne on aerial mycelium, sickle-shaped; or none. Acid-color modification of aerial mycelium yellow except in *F. anthophilum* (A. Br.) Wr., and other related fungi; conidial walls thin---Sec. 7, *Roseum.*
ee. Top ends of macroconidia somewhat constricted.
f. Conidial walls thin, and in this character, as well as in shape and color, similar to section Elegans---Sec. 9, *Lateritium.*
ff. Conidial walls thick, highly refracable, and in this character, as well as in shape and color, similar to section Discolor; conidial stage of *Gibberella saubinetii* and other similar Gibberellas---Sec. 12, *Saubinetii.*

RELATIONSHIP OF FUSARIA TO ASCOMYCETES

A number of different species of Fusaria have been definitely connected with certain ascomycetes of the Hypocreales group. In some other cases the connection is very probable, and in still other cases the connection is suggested as possible. For convenience the instances are mentioned here under different sections of the genus Fusarium.

Sec. 1. Eupionnotes. Perfect stage, *Nectria moschata* Glück, conidial stage similar to *F. aquaeductuum* Lagh. var. *pusillum* Wr.

Sec. 2. Arachnites. Perfect stage, *Galonectria graminicola* (Berk. & Brome) Wr., conidial stage *F. nivale* (Fries) Ces.

Sec. 3. Sporotrichiella. No connection with an ascomycete is known.

Sec. 4. Camptospora. Perfect stage *Nectria episphaeria* (Tode) Fr., conidial stage may be *F. cavispermum* Cda.

Sec. 5. Arthrosporiella. No definite connection with an ascomycete is known.

Sec. 6. Gibbosum. No connection with an ascomycete is known.

Sec. 7. Roseum. *Gibberella tropicalis* Rehm. possibly has Roseum-like conidial stage.

Sec. 8. Liseola. *Gibberella acervalis* (Moug.) Wr., conidial stage very similar to *F. moniliforme* Sheld.

Sec. 9. Lateritium. *Gibberella baccata* (Wallr.) Sacc., conidial stage *F. lateritium* Nees; *G. pulicaris* (Fr.) Sacc., conidial stage *F. sarcochroum* (Desm.) Sacc.; *G. moricola* (Ces. et Not.) Sacc., conidial stage *F. urticearum* (Cda.) Sacc.; *G. effusa* Rehm, conidial stage *F. salicis* Fuck.; *G. evonymi* (Fuck.) Sacc., conidial stage *F. pyrochroum* (Desm.) Sacc.; *G. juniperi* (Desm.) Wr., conidial stage *F. fructigenum* Fr.

Sec. 10. Discolor. *Gibberella heterochroma* Wr., conidial stage *F. polymorphum*-like; and *G. cyanogena* (Desm.) Sacc., conidial stage *F. sambucinum* Fuck.

Sec. 11. Spicarioides. No connection with an ascomycete is known.

Sec. 12. Saubinetii. *Gibberella saubinetii* (Mont.) Sacc., conidial stage *F. graminearum* Schwabe; *G. flacca* (Wallr.) Sacc., conidial stage *F. caricis* Oud.

[9] Subsection Eugibbosum n. subsect.
[10] Subsect. Ferruginosum (Sect. Ferruginosum Sherb.) n. comb.

Sec. 13. Elegans. No connection with an ascomycete is known.
Sec. 14. Martiella. *Hypomyces ipomoeae* (Hals.) Wr., conidial stage *F. javanicum* Koord.; *Hypomyces cancri* Wr., conidial stage *F. striatum*-like; *Hypomyces leptosphaeriae* (Niessl) Wr., conidial stage *F. sphaeriae* Fuck.
Sec. 15. Ventricosum. *Hypomyces solani* Rke. et Berth., conidial stage *F. argillaceum* (Fr.) Sacc.

NOMENCLATURE IN RELATION TO SPECIES, VARIETIES, AND FORMS

The plan recently considered and approved by the committees of the Phytopathological Society, the Society of Agronomy, and the Mycological section of the Botanical Society on June 6, 1924, in Washington, D. C., is followed in regard to questions of nomenclature and terminology. This plan provides for the use of the Latin trinomial composed of the genus, species, and variety. The *species* includes groups of individuals which can be separated on the basis of morphological character of such a nature as to be applicable and usable by mycologists in general and which will be most serviceable for practical purposes. The *variety* is distinguished by morphological characters, but less important than those used for specific segregation. An additional category termed *forma* is to be applied to subdivisions of the species or varieties characterized and distinguished primarily by physiological instead of morphological characters, though in some instances there may be present also some slight morphological, distinguishable differences. The *forma* is designated by an arabic numeral.

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