THE GLADIOLUS DRY ROT CAUSED BY SCLEROTINIA GLADIOLI (MASSEY) N. COMB.[1, 2]

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This disease is of importance in the growing of gladioli in commercial plantations as well as in private gardens. It has received some attention from the pathological point of view and its causal fungus has been studied and described (1, 6). The prominent structure of the fungus is a minute sclerotium, and the failure to find any functional spores, either on diseased plants or in artificial cultures, made it necessary to designate it as one of the Mycelia Sterilia under the binomial *Sclerotium gladioli* Massey (6).

While working with several sclerotium-producing fungi, it was found that this fungus will develop fruiting bodies as the result of a sexual process. The microconidia noted by Massey, and an ascogonial system in receptive structures, comprise the sexual components that accomplish the formation of apothecia of the Sclerotinia type. The recognition of a perfect stage makes it possible to extend our knowledge of this pathogen, and the purpose of this paper is to propose a new combination for its designation and to record the emended diagnosis. A number of new suscepts have been encountered in the course of this work. These will be mentioned, together with some historical facts relative to the disease and the pathogen.

THE SEXUAL NATURE OF THE FUNGUS

The fact that fruiting bodies of this fungus develop as the result of a sexual process has already been reported in a brief preliminary paper (2). A description of the technique used to induce the development of apothecia, together with other facts relating to the sexual mechanism of this fungus, has been published in a separate paper (3). It may not be out of place, however, to refer to some of these points here.

The microconidia of *Sclerotinia gladioli* are similar in shape and manner of production to those that have been recorded in several species of Sclero-

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[2] Part of this work is taken from a thesis submitted to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy and the rest was done during the tenure of a National Research Fellowship in the Biological Sciences at the Laboratories of Cryptogamic Botany, Harvard University.

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tinia, Botrytis, and Sclerotium. Their function hitherto has always been obscure, but this investigation established the fact that they are spermatia. The receptive structures containing the coiled ascogonial system arise from a stromatic layer formed on the surface of substrates rich in carbohydrates. The spermatization of these with microconidia from a compatible isolate of the fungus results in the development of apothecia. In the absence of spermatia, or if microconidia from the same or an incompatible isolate are used for spermatization, there may be some elongation of the receptive bodies but no development of apothecia. Each monomycelial or monoascosporic culture gives rise to both receptive bodies and microconidial sporodochia when subjected to favorable conditions, but such cultures are self-sterile, reciprocally intersterile with some isolates (incompatibles), and interfertile with others (compatibles). There exists, therefore, the phenomenon of monoecism, if one may use this term to designate the presence of both sexual organs on the same fungus thallus, with the separation of various isolates into 2 groups exhibiting reciprocal intragroup sterility, intergroup fertility, while each isolate itself is self-sterile.

THE DISEASE AND THE PATHOGEN

Sclerotinia gladioli is responsible for a necrotic disease, known as dry rot, of the gladiolus and certain allied plants. The outstanding symptom is premature death brought about by the invasion and decay of the subterranean organs, including the basal portion of the leaf sheaths, while on the corms and cormels characteristic lesions are produced, often accompanied by vascular necrosis and mummification. On the decayed parts of the leaf sheaths, on the corm scales, and sometimes in or on the corm lesions are formed minute sclerotia, which serve as organs of resistance. The stroma, referred to above, is formed within badly diseased corms.

The first work of any importance done on this disease was by Wallace,[4] who applied the name dry rot to one of the 4 diseases of gladiolus corms that he studied. He suspected that he was including 2 diseases under this name, and, judging from his descriptions and photographs, this was the case. In addition to the true dry rot, he apparently had material of a common but undescribed storage disease of the corms caused by *Botrytis* sp. His description of one of the fungi isolated from gladiolus corms from Germany and New York State is unquestionably that of *Sclerotinia gladioli*. Two years later, Fitzpatrick (4) restricted the use of the name dry rot to the disease as now recognized.

Even before 1909, however, this disease seems to have been seen, although not recognized as such, for Wallace thinks that this was probably

[4] Wallace, E. Some bulb rots of gladioli. Unpublished thesis. Cornell University, 1909.

the disease referred to by Robinson (8, p. 139) in 1883 in England. Yet Wallace and other investigators have overlooked an article in 1906 by Ritzema-Bos (7) in which he describes a disease occurring on gladiolus and montbretia plants in Sassenheim, Holland. It is quite clear that his material consisted of plants affected with dry rot.

These several investigators all observed the development of small sclerotia by the causal fungus and noted the absence of sporulation. Hence, in 1918, Massey (5) proposed that it be placed in the form genus Sclerotium, and subsequently the present writer (1) referred to it as *Sclerotium* sp. in 1926. In 1928 Massey (6) erected the binomial *Sclerotium gladioli* and, as he observed for the first time the presence of microconidia, he suggested that the fungus might be a Sclerotinia because of the structure of these bodies and of the sclerotium, even though his attempts to bring about the development of apothecia were unsuccessful. These microconidia were found by Massey in 25- to 40-day-old test-tube cultures, where they appeared as small white granules less than 1 mm. in diameter, buried in the medium at the back of the slant adjacent to the wall of the tube. The writer finds, however, that by using Petri-dish cultures composed of plant stems and potato–2 per cent dextrose agar it is now possible to obtain more numerous and larger microconidial sporodochia in 12 to 18 days.

All of the papers dealing with this disease hitherto have noted its occurrence on the several varieties of the large-flowering gladiolus included in hybrids of the species *G. primulinus, G. communis,* etc. In the course of the present investigation, however, certain additional suscepts have been encountered among other genera of the Iridaceae. During a visit to Holland in 1928, an examination of crocus corms as they were brought in from the field revealed the presence of this disease in a great many cases. In the same locality, also, under greenhouse culture, it was found on plants of *Lapeirousia (Anomatheca) cruenta* Baker and in field culture on *Tritonia (Montbretia) crocosmaeflora* Lemoine. Rather severe infections were observed on freesia plants in several greenhouses in Long Island, New York, in 1929, and in shipments of corms of this plant from Southern Europe to Canada. In all of these instances, the causal fungus was isolated and its identity confirmed. In connection with the question of host ranges, it is of interest to note here that when several varieties of rhizomatous iris, tulip, hyacinth, and narcissus were planted by the writer in soil from which gladiolus plants exhibiting 100 per cent infection had just been harvested, these plants all grew well and never showed any sign of infection. These tests, although limited, were sufficiently conclusive to justify mentioning them here, for a knowledge of the range of resistance and susceptibility among the commoner bulbous and rhizomatous ornamental plants may be of importance to the nurseryman and gardener in arranging the rotation of their plantings.

EMENDED DIAGNOSIS

The recognition as sexual elements of the microconidia and the receptive structures developed by the stroma, and the manipulation of these with resulting production of a fruiting body, now makes it possible to give a complete technical description of this fungus, as follows:

Sclerotinia gladioli (Massey) n. comb.

Synonymy—*Sclerotium gladioli* Massey L. M.
Phytopath. **18**: 519–529. 1928.

Mycelium septate, inter- and intracellular, multinucleate; in culture white, aerial portions tipped with buff when old, emitting a musty odor.

Sclerotia black, 90–240 x 90–300 μ, average 191 x 164 μ, consisting of a well-defined and compact rind of thick-walled cells surrounding a thin-walled, pseudoparenchymatous medulla, the cells of which are filled with small globules of oil (Fig. 1, A).

Stromatic tissue formed on substrates rich in carbohydrates, at temperatures of 18° to 24° C. Usually firmly attached to the substrate. Black, varying in thickness from 80–500 μ, with a rind of loosely aggregated, closely septate, black, thick-walled hyphae, and a prosenchymatous, hyaline medulla (Fig. 1, A).

Receptive bodies formed from the stromatic layer, .8 to 1.9 mm. tall, depending on age, .4 to .8 mm. broad, columnar, often branched, tapering to a rounded apex or occasionally slightly capitate, light brown, pilose, and covered with a thin layer of a mucilaginous substance. These bodies possess an external region of loosely interwoven, thick-walled, septate hyphae, hyaline towards the apex, becoming progressively darker towards the base and merging with the black hyphae of the stromatic rind. Within this, a region of light brown, densely packed hyphae, somewhat interwoven but running longitudinally and giving rise to an apical tuft of thinner-walled, septate hyphae that arch inwards to form a depression at the center of the apex. In the center is found a column of hyaline, less compact tissue composed mainly of a sparsely-septate, intricately coiled, multinucleate ascogonial system, which is terminated at the apex by trichogynous hyphae with their tips clustered beneath the overarching apical hyphae. On fertilization these structures develop into apothecia (Fig. 1, A, B, D).

Microconidia globose, 1.2–1.8 μ in diameter, uninucleate, and incapable of germination, but functioning as spermatia. Produced in a sporodochium made up of closely septate hyphae that give rise to numerous clusters of verticillately branched conidiophores that end in tapering, elongate, slightly

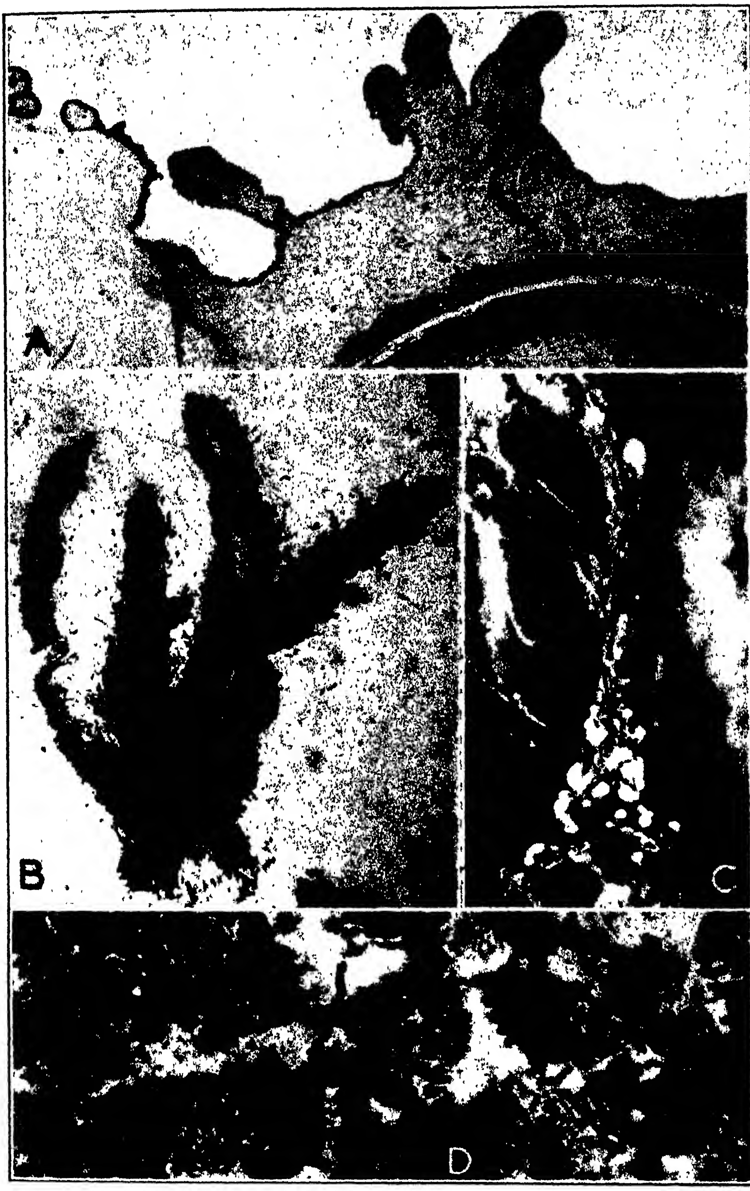

FIG. 1. A. Receptive bodies arising from the stroma formed on grain of wheat, a portion of which is evident at the lower right. Note the thin loosely constructed rind of the stroma as compared with the thicker and more compact rind of the three sclerotia at the upper left. ×30. B. Branched receptive body showing the coiled ascogonial hyphae in the central core. ×35. C. Microconidial sporodochia. ×4.5. D. Part of a Petri-dish culture with receptive bodies. ×4.5.

bent terminal cells on which the microconidia are developed successively in vast numbers embedded in a mucilaginous matrix, which, on drying, gives a waxy consistency to the whole sporodochium (Figs. 1, C and 2, C).

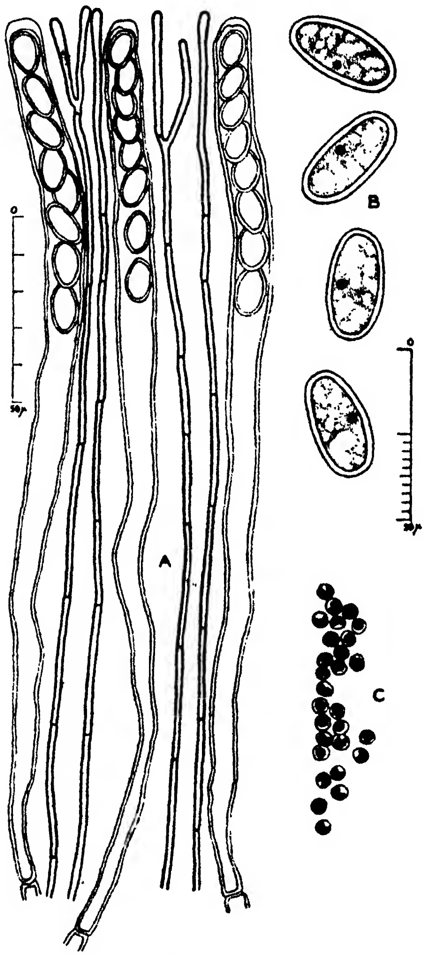

FIG. 2. A. Asci, ascospores, and paraphyses. B. Ascospores more highly magnified. C. Microconidia, magnified to the same extent as the ascospores.

Apothecia densely cespitose, stipitate, 3 to 7 mm. broad, 6 to 10 mm. high. Disc cinnamon brown, stipe chestnut brown (Ridgway). Hymenial surface umbilicate, convex-discoid. Margin strongly reflexed, deeply-crenate, sometimes entire or convolute. Lower surface tomentose, less densely so down the stipe. Context thick, prosenchymatous, infundibuliform, with a definite hypothecium (Fig. 3A, B, and C). Asci cylindrical to cylindro-clavate, opening by a pore, 190.5–235.4 x 8.5–9.2 μ, average 212.5 x 9.06 μ. Ascospores 8, unicellular, uniseriate, ellipsoidal, hyaline, uninucleate, 10.2–

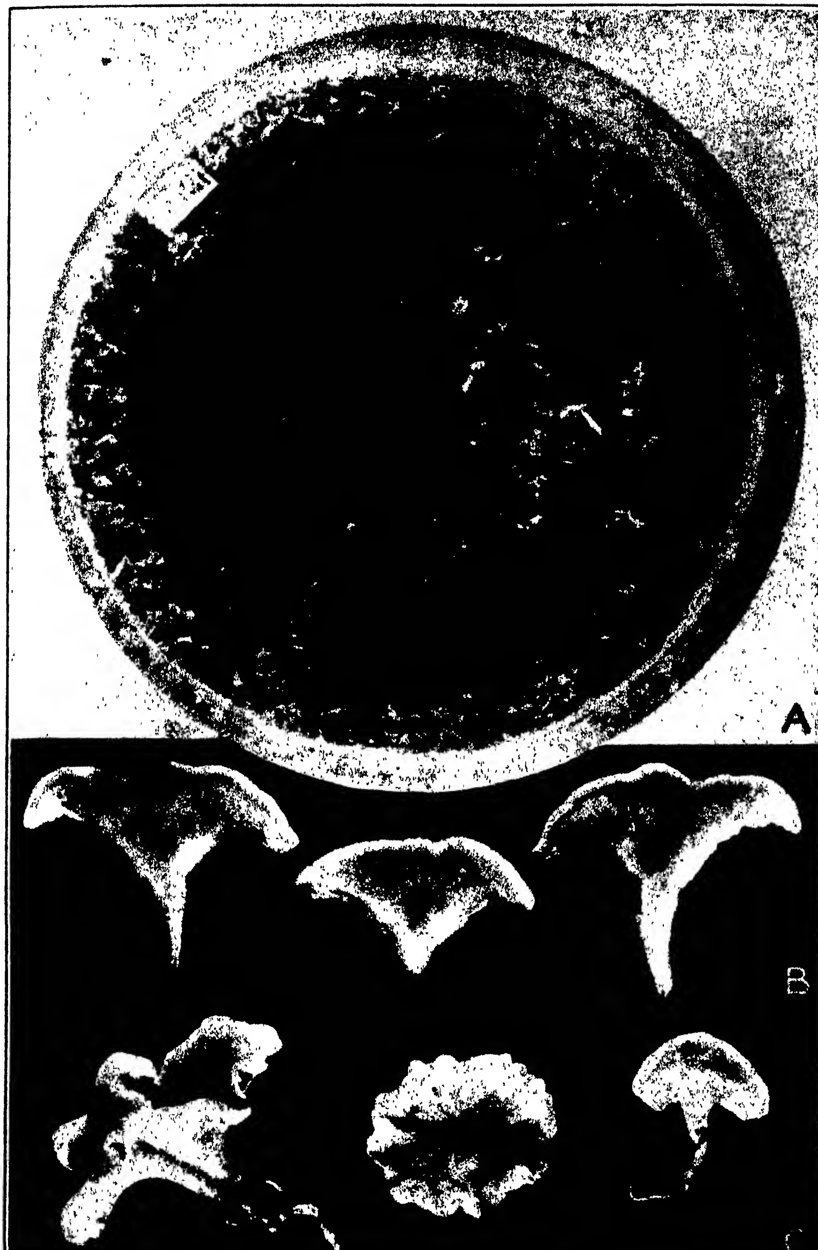

FIG. 3. A. Petri-dish culture bearing numerous apothecia. × .8. B. Longitudinal sections of apothecia. Note hypothecium, thick medullary excipulum, and tomentose excipulum. × 3.4. C. Three apothecia showing variation in shape. × 4.2.

16.75 x 5.6–9.5 μ, average 14.04 x 7.25 μ, mode 13.5 x 7.25 μ. Paraphyses abundant, filiform to slightly clavate at apex, septate, hyaline 2.8–3.2 μ diam. (Fig. 2, A and B).

The cause of a necrotic disease known as dry rot, on the following suscepts:—All cultivated varieties of *Gladiolus* spp., *Tritonia* (*Montbretia*) *crocosmaeflora* Lemoine, *Freesia* spp., *Lapeirousia* (*Anomatheca*) *cruenta* Baker, and *Crocus* spp.

Known distribution—United States, Canada, England, Scotland, Ireland, Holland, Germany, France, and New Zealand.

Type specimens of apothecia deposited in the Plant Pathology Herbarium, Cornell University, Ithaca, N. Y. No. 20136. Also in the Farlow Herbarium, Harvard University, Cambridge, Mass.

SUMMARY

The dry-rot disease of gladioli has been known for several years and its importance appreciated. The causal fungus apparently developed no functional spores and hence was named *Sclerotium gladioli* by Massey in 1928.

A sexual mechanism has now been discovered that involves the microconidia and the pilose receptive structures developed from a stroma. The sexual interaction of these yields apothecia of the Sclerotinia type. The life cycle of the fungus is, therefore, now completely known and its taxonomic relationship can be established.

The historical events of importance in connection with this disease and its pathogen are given.

The resistance and susceptibility of several common ornamental plants are mentioned and a member of new suscepts are recorded.

The new combination *Sclerotinia gladioli* (Massey) is proposed and a detailed emended diagnosis is given.

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