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TB 258 (1971) USDA TECHNICAL BULLETINS UPDATA
FUNGOUS DISEASES OF THE CULTIVATED CRANBERRY
SHEAR, C. L., STEVENS, N. E., BAIN, H. F. 1 OF 1



UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

FUNGOUS DISEASES OF
THE CULTIVATED CRANBERRY

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INTRODUCTION

This bulletin summarizes the results of 30 years' study of the fungous diseases of the cultivated cranberry (*Vaccinium macrocarpon* Ait.).¹ At various times during the progress of these investigations results have been published in bulletins of the United States Department of Agriculture, in bulletins of the experiment stations with which cooperative investigations were in progress, in scientific journals, and in the proceedings of the various cranberry growers' associations. An attempt is here made to assemble all this information.

In addition to compiling the material already published, the results of recent unpublished work are included. The descriptive list of fungi includes all that are known to cause diseases of the cranberry as well as such additional species as have been identified since the last general publication on cranberry fungi appeared.

As this summary of work on fungous diseases of the cranberry is designed for reference, the material is presented from three more or

¹ It is a pleasure to acknowledge the assistance received during the progress of this work from a large number of those commercially interested in cranberries, both growers and those associated with sales organizations. Special thanks are also due the authorities of experiment stations and the departments of agriculture in the cranberry-producing States, whose cordial cooperation has made it possible to study cranberry diseases on a national scale.

less distinct points of view, represented by separate sections of the bulletin. The sections differ not only in content but in method of presentation, and are designed for somewhat different classes of readers. Those who are chiefly interested in cranberry diseases and their control will read first the pathological section, pages 40 to 51, with such references to the other parts as may seem worth while. The section on physiology of rot fungi contains material of interest chiefly to students of the physiology, distribution, and ecology of fungi, and to those concerned with the fungous diseases of fruits. The taxonomic section is made up chiefly of illustrated descriptions of fungi known to occur on the cranberry. It is hoped that this will be useful to those who wish to identify cranberry fungi or related species.

TAXONOMY

For convenience in reference, the fungi discussed in this bulletin are divided into three groups—the important fungous rots, those fungi causing vine diseases, and fungi found on cranberries but not now known to be of commercial importance. Obviously, this division is highly artificial.

Group 1 contains fungi which have become recognized as major causes of fruit rot. These rot fungi have been more intensively studied than the others, and the discussions on physiology and pathology relate chiefly to them. Group 2 contains fungi known to cause vine diseases of cranberries. The fungi in Groups 1 and 2 are arranged in the order of their importance. The third group is made up of fungi found on cranberries, on either leaves or stems of growing plants, on dead plant parts, or isolated occasionally from decayed berries, but which are apparently of no commercial importance. The fungi in Group 3 are arranged alphabetically under the headings Ascomycetes, Uredineae, and Fungi Imperfecti. Probably no justification is needed for including descriptions of such fungi in a bulletin of this type. It may almost be said that any fungus that grows on a cultivated host is worthy of study even from a purely practical viewpoint. Changed conditions of culture or even a new point of view in the study of disease may wholly change our estimate as to the significance of some of these fungi. For example, at the time of the first publication on the subject of cranberry diseases (61), no mention was made of a fungus which had appeared a few times in cultures from rotten cranberries and was characterized by an abundant yellow mycelial growth. The extension of our studies of the cranberry to include the storage period and a more intensive study of northern cranberry-growing regions has demonstrated that this, the end-rot fungus, is commercially the most important fungus now known to affect cranberries.

IMPORTANT ROT FUNGI

Godronia cassandrae Peck, 1886 (*pt.*, p. 50)²

SYNONYMS:

Pyrenidium: *Dothiopsis myrtilli* Feltg., 1903 (*19*, p. 285-286).

Leptothyrium oryzae Shear, 1907 (*60*, p. 311).

Fusicoccum putrefaciens Shear, 1917 (*62*, 64).

Strocipulina myrtilli (Feltg.) Petrak, 1924 (*53*, p. 37-39).

²Table numbers in parentheses refer to Literature Cited, p. 52.

Pycnidia.—Subglobose to pyriform, rather thick-walled, more or less roughened, tawny to tawny brownish, embedded at first, becoming erumpent or sub-superficial when mature, sessile or subsessile, simple or irregularly chambered forms 160–400 μ in diameter, larger chambered forms 400–450 μ ; spores elliptic to fusiform, hyaline or very faintly yellowish in mass, continuous or pseudo-septate, 8–18 by 2–3 μ , mostly 10–12 by 2.5 μ ; sporophores simple or branched, cylindrical or somewhat tapering above, 20–36 by 2 μ . (Fig. 1.)

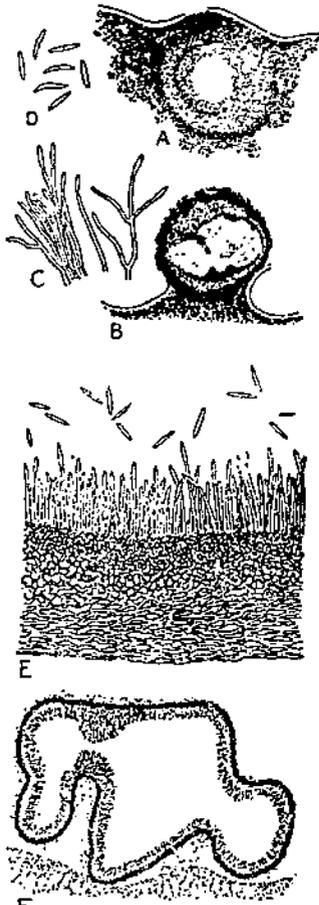


FIGURE 1.—*Godronia cassandrae*, pycnidial stage: A, Section of young pycnidium on cranberry, $\times 43\frac{1}{2}$; B, section of nearly mature pycnidium, $\times 43\frac{1}{2}$; C, sporophores, $\times 420$; D, pycnospores, $\times 420$; E, sporophores and spores in culture on *Mellilotus* stem, $\times 420$; F, section of pycnidium from cornmeal agar culture, $\times 43\frac{1}{2}$. After Shear (61)

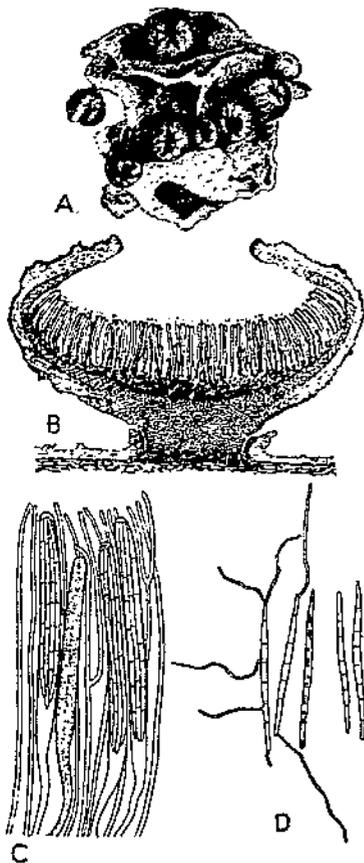


FIGURE 2.—*Godronia cassandrae*, apothecial stage: A, Apothecia on mummled cranberry, $\times 6$; B, section of apothecium on cranberry stem, $\times 36$; C, asci and paraphyses, $\times 430$; D, mature and germinating ascospores, $\times 318$. After Shear and Bain (64)

Apothecia.—Small, on cranberry and *Cassandra* stems 0.5–0.7 mm. in diameter, on cranberry fruits 0.5–1.8 mm.; sessile or nearly so, depressed, urceolate, tawny brown, the hymenium whitish or livid when moist, darker when dry, margin entire or slightly dentate-lacerate, almost closed when dry; asci cylindrical, 58–117 by 5–10 μ ; spores hyaline, filiform, nearly straight, 4–7, mostly 6–7 septate when mature, nearly straight, 50–70 μ long; paraphyses filiform, numerous, exceeding the asci, often branching toward the apex. (Fig. 2.)

Type specimen.—On *Cassandra calyculata*² (64), Karner, N. Y., August, 1885, in New York State Museum.

Specimens examined.—On *Vaccinium macrocarpon* and *Cassandra calyculata* in mycological collections, Bureau of Plant Industry; on *V. myrtilus* Petrak, No. 1609.

Cultural characters.—On corn-meal agar in Petri dishes, colonies 12 days old, observed by transmitted light, are white at the margin, passing through pale lemon yellow and yellow chrome to orange citrine at the center, and when older on slant agar tubes of this medium became La France pink to Mars orange. On sterilized stems of *Melilotus siba* the growth passes through the same shades during its early development, but finally becomes nopal red or even garnet brown spots. The pycnidial fruiting stage alone has been produced in cultures.

Hosts.—*Vaccinium macrocarpon*, *V. vitis-idaea*, *V. oxycoccos*, *V. caespitosum*, *V. myrtilus*, and *Cassandra calyculata*.

Geographical distribution.—Maine, Massachusetts, New York, New Jersey, North Carolina, Michigan, Wisconsin, Oregon, Washington, Alaska, and Bohemia.

Pathological relation.—The cause of end rot, the most important storage rot of the cranberry. Typically a late storage rot.

Guignardia vaccinii Shear, 1907 (60, p. 316)

SYNONYMS:

Described and figured without a name, B. D. Halsted, 1889 (30, p. 33-35).

Described and figured without a specific name by C. L. Shear, 1905 (59, p. 6, figs. 1-4).

Mycosphaerella oxycocci Dearness and House, 1923 (15, p. 76).

Pycnidia.—Minute, black, membranous, globose, 100-120 μ in diameter, with a minute apical, sometimes slightly prominent ostiole, subepidermal, usually hypophyllous, slightly erumpent with minute ostiole exposed, thickly and evenly distributed over surface; spores hyaline, obovoid with apex frequently truncate, 10.5-13.5 by 5-6 μ , coarsely granular, bearing at apex a rather inconspicuous curved appendage consisting of granular matter embedded in a gelatinous

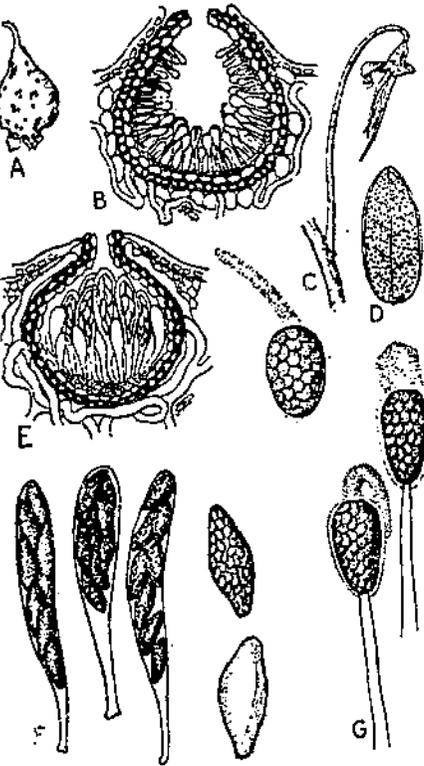


FIGURE 3.—*Guignardia vaccinii*: A, C, and D, Pycnidia on fruit, stem, and leaf; B, section of pycnidium, $\times 190$; E, section of perithecia, $\times 190$; F, ascus, $\times 545$, and ascospores, $\times 1,000$; G, pycnospores, $\times 1,000$. After Shear (61)

substance, about same length as spore; sporophores simple, 10-15 μ long. (Fig. 3, A, B, C, D, G.)

Perithecia.—Resemble pycnidia very closely in form, size, and other characteristics; walls somewhat denser and more opaque than in pycnidia; asci 8-spored, oblong or somewhat clavate, short stipitate or sessile, 60-80 by 9-12 μ ; spores hyaline or slightly yellowish brown when old, short elliptical or subrhomboidal, 13-16.5 by 6-7 μ , contents coarsely granular; paraphyses none. (Fig. 3, E, F.)

²The equivalent of this and other host-plant names mentioned in this bulletin, when they differ from those used in Standardized Plant Names (1), will be found on p. 52.

³RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., illus. Washington, D. C. 1912.

Type specimen.—No. 1476, C. L. S., on leaves of *Vaccinium macrocarpon*, near Lakewood, N. J., September 4, 1901.

Cultural characters.—Grows readily on corn-meal agar and numerous other media. Mycelium on all media tested at first thin, floccose, white, becoming in a few days bluish gray. In older cultures the mycelium spreads concentrically and becomes grayish brown. Pycnidia appear in from 4 to 8 days and mature pycnospores in from 12 to 18 days. Pycnidia form a more or less continuous layer on the surface of the somewhat felty mycelium. Usually pycnidia alone are produced in cultures, but occasional strains occur which may produce both pycnidia and perithecia.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Nova Scotia, Massachusetts, New York, New Jersey, West Virginia, Wisconsin, Oregon, and Washington.

Pathological relations.—One of the most important cranberry fungi, causing blast or blight of flowers and young fruit in New Jersey and early rot of fruit in storage in New Jersey and Massachusetts and to a less degree in Wisconsin, Washington, and Oregon.

Glomerella cingulata vaccinii Shear, 1913 (70, p. 43)

SYNONYM:

Glomerella rufomaculans vaccinii Shear, 1907 (61, p. 30-35).

Acervuli.—Small, on leaves or decayed berries, subepidermal, erumpent when mature; conidia extruded in a mass, hyaline or flesh-colored, oblong elliptical or sometimes slightly smaller at one end, 12-18 by 4.5-6 μ ; conidiophores simple, tapering upward, 15-20 μ long. (Fig. 4, A, B, C.)

Perithecia.—Known only in culture; submembranous, globose to slightly pear shaped, usually somewhat buried in the felty mycelial growth, 250-300 μ ; asci 8-spored, clavate, sessile or short stipitate, 60-72 by 10-12 μ ; ascospores irregularly biseriata, oblong elliptical, occasionally slightly inequilateral or curved, hyaline at first, pale greenish yellow when fully mature, 9-18 by 5-7.5 μ ; paraphyses none. (Fig. 4, D, E.)

Type specimen.—Slide No. 1447-A, C. L. S., from culture from single ascospore. Original source of material was leaves of *Vaccinium macrocarpon* from New Jersey.

Cultural characters.—Grows rapidly on corn-meal agar, producing rather dense white mycelium which eventually forms a compact layer. Acervuli begin to appear in three to four days at room temperature.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Massachusetts, New Jersey, Wisconsin, Oregon, and Washington.

Pathological relations.—Causes bitter rot of cranberry fruit, which in some seasons is an important storage rot in Massachusetts and New Jersey; less common in Wisconsin and in the Pacific coast cranberry district.

Acanthorhynchus vaccinii Shear, 1907 (60, p. 314)

Imperfect stage.—None known.

Perithecia.—Hypophyllous, scattered, depressed globose to pyriform, subepidermal, 300-400 μ in diameter, ostiole erumpent; beak with black nonseptate spines 50-70 by 8-9 μ at the base; wall of perithecium membranous, consisting of a single layer of cells; asci 8-spored, clavate, short-stipitate, 136-180 by 30-48 μ ; paraphyses stout, septate, occasionally branching near ends, 200-340 by 5-8 μ ; ascospores biseriata or irregularly uniseriate, hyaline until almost mature, pale yellowish brown when mature, oblong elliptical, densely granular, 27-36 by 12-20 μ . (Fig. 5.)

Type specimen.—No. 1493, C. L. S., on leaves of *Vaccinium macrocarpon*, West Mills, N. J., September, 1901.

Cultural characters.—Grows readily on corn-meal agar, forming a rather close white layer. The mycelium later assumes a uniform dirty ochraceous color, which is soon followed by the development of the dark perithecia, distributed more or less uniformly over the surface of the culture medium, and partly covered by the mycelium. Mature perithecia are produced at room temperature within 14 to 30 days.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Nova Scotia, Massachusetts, New Jersey, West Virginia, Wisconsin, Oregon, and Washington.

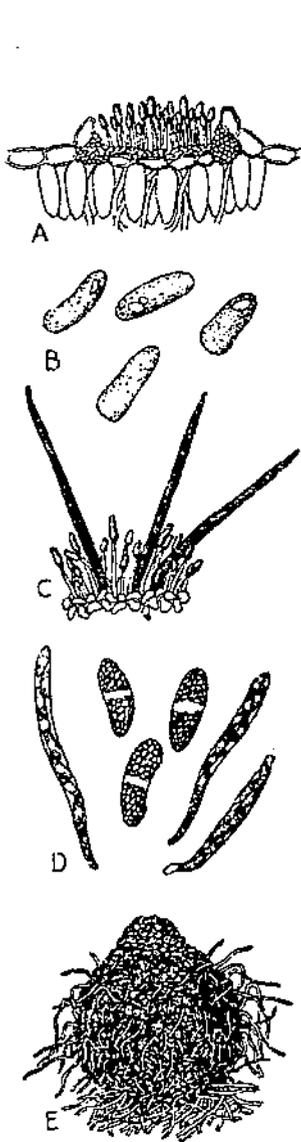


FIGURE 4.—*Otomerella cinquifida vaccinii*: A, Acervulus on cranberry leaf, $\times 400$; B, conidia, $\times 800$; C, conidiophores and setae, $\times 400$; D, asci, $\times 400$, and ascospores, $\times 800$; E, perithecium, $\times 80$. After Shear (61)

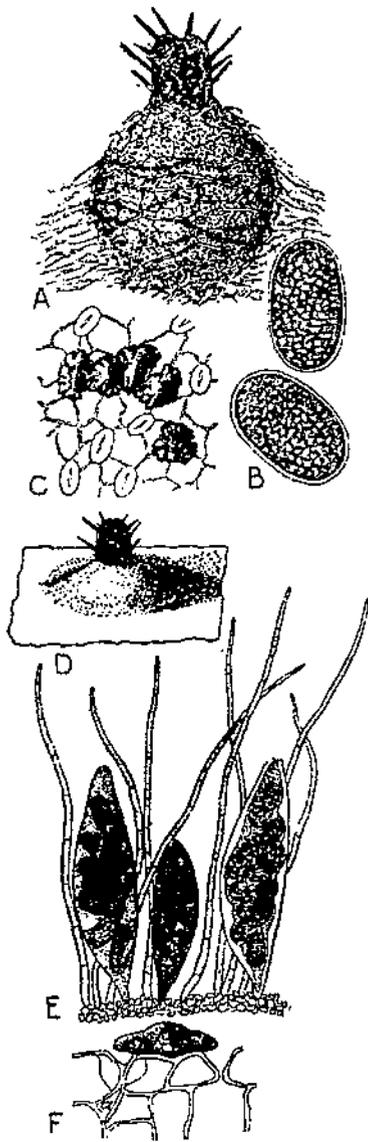


FIGURE 5.—*Acanthorhynchus vaccinii*: A, Perithecium, $\times 70$; B, ascospores, $\times 540$; C, appressoria attached to cranberry leaf; D, protruding neck of perithecium on leaf, $\times 35$; E, asci and paraphyses, $\times 200$; F, germinating appressorium. After Shear (61)

Pathological relations.—The cause of blotch rot, a common storage rot of cranberries in New Jersey, less important in Massachusetts, Wisconsin, and the Pacific coast districts.

Diaporthe vaccinii Shear, n. sp.

SYNONYM:

Pycnidia: Phomopsis vaccinii, n. f. nom.

Pycnidia.—Vary in size and shape with the substratum on which the fungus is grown, from about 0.3–0.5 mm. in diameter on cranberry fruit to 1–2 mm. in corn-meal and potato-dextrose agar cultures; pycnidia in agar cultures partly embedded, thick-walled, black, leathery, usually

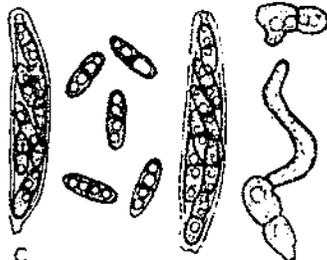
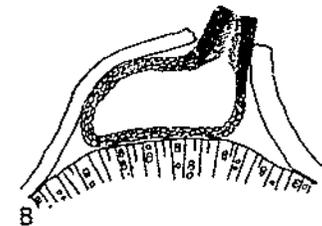
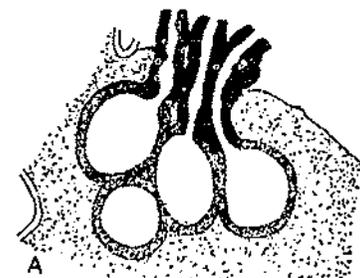


FIGURE 7.—*Diaporthe vaccinii*; perithecial stage: A, Section of group of perithecia on cranberry fruit, $\times 34$; B, section of perithecium on cranberry stem, $\times 68$; C, asci, ascospores, and germinating ascospores, $\times 430$

spherical, 0.3–0.5 by 0.2–0.4 mm.; wall two to several cell layers thick, black, carbonous; on decayed berries perithecia in stromata, with long perithecial necks protruding in all directions from folds of the shriveled berry; in corn-meal agar cultures perithecial stromata are partly embedded, about 1.5–2 mm. in diameter, with numerous beaks growing to a length of 0.5 mm.; perithecial necks several cells thick, heavy-walled, black, carbonous, copiously supplied with upward-directed hairs; asci oblong fusoid, sessile, 37–51 by 6.8–11.7 μ , apex thickened and pierced by a narrow pore; spores irregularly biseriolate, ellipsoid, obtuse, 2-celled, slightly constricted at the septum, each cell typically bicarinate, 8.8–11.8 by 2.4–3.4 μ . (Fig. 7.)

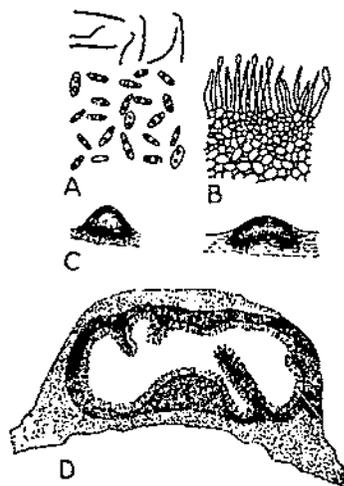


FIGURE 6.—*Diaporthe vaccinii*; phomopsis stage: A, Pycnospores and scolecospores, $\times 350$; B, sporophores and section of pycnidial wall, $\times 350$; C, pycnidia on *Mellilotus* stem, $\times 21$; D, section of pycnidium from corn-meal agar culture, $\times 21$

chambered, rupturing irregularly to emit whitish or slightly pinkish masses of spores; spores hyaline, 1-celled, long-elliptic, typically with two prominent oil globules, 6–11 by 2–5 μ ; sporophores simple, tapering toward apex, somewhat spindle shaped, about 15–25 μ long in young pycnidia, somewhat longer in older pycnidia; scolecospores observed but once, in culture grown on boxelder twig, abundant, 14–20 by 0.35 μ , usually hamate. (Fig. 6.)

Perithecia.—In stromata on cranberry fruit and in culture, but separate and without any trace of stroma on dead cranberry vines; perithecia on stems grow between bark and wood, with eccentric neck protruding through the bark, nearly hemispherical.

Type specimen.—On *Vaccinium macrocarpon*, Clatsop, Oreg., collected by H. F. Bain, 1924. Deposited in mycological collections, Bureau of Plant Industry.

Cultural characters.—On corn-meal agar growth is white, closely appressed over most of surface, but with a few small patches of denser white aerial mycelium from 1-2 mm. in diameter, which eventually develop into thick, tough stromalike bodies, black on the exterior, partly embedded in substratum, in which both pycnidia and, more rarely, perithecia, are formed. Melilotus stems furnish the best medium for spore production. Growth at first is white, with considerable aerial mycelium, later darkening and forming large areas of black leathery tissue in the bark. Pycnospores are produced within one week at room temperature.

Hosts.—*Vaccinium macrocarpon* and *V. oxycoccos intermedium*.

Geographical distribution.—Massachusetts, New Jersey, Wisconsin, Oregon, and Washington.

Genetic relationship between Phomopsis and Diaporthe.—In 1924 several single ascospore isolations from Diaporthe, both from the stromatic form on berry and from separate perithecial form on stems of *Vaccinium macrocarpon* and *V. oxycoccos intermedium*, all produced typical Phomopsis colonies and pycnospores in culture, but no perithecia. Out of 150 cultures of Phomopsis on corn-meal agar made from decaying berries in the fall of 1923 and held over winter in an unheated building in Oregon, 33 per cent produced perithecia by May, 1924. A fair proportion of these cultures showed both pycnidia and perithecia in the same stroma. All other attempts to induce perithecial formation in culture have failed.

Pathological relations.—An important cause of storage rot of cranberries.

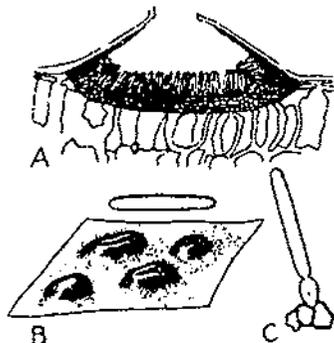


FIGURE 8.—*Sporoneva oxycocci*: A, Vertical section from cranberry leaf, $\times 200$; B, pycnidia on leaf; C, spore and sporophore $\times 775$. After Shear (61)

Sporoneva oxycocci Shear, 1907 (60, p. 308)

Pycnidia.—Excipuliform, thickened at the base, gradually disappearing above, arising beneath the epidermis and becoming erumpent, depressed globose, dark brown, gregarious or scattered, amphigenous, 50-100 μ in diameter, sometimes collapsing, rupturing irregularly by a slit or triangular split; sporophores simple, oblong or subglobose, about one-fourth the length of the spore or less; spores hyaline, cylindrical, straight, continuous, 15-20 μ by 3-4 μ ; contents homogeneous. (FIG. 8.)

Type specimen.—No. 1484, C. L. S., (on slide) on head leaf of *Vaccinium macrocarpon*, Wareham, Mass., H. J. Franklin collection, May, 1906. Also No. 1485, C. L. S., Cape Cod, Mass., September, 1906, and No. 1486, C. L. S., Whitesville, N. J., September 2, 1904.

Cultural characters.—On corn meal, mycelium at first whitish, forming a compact thin layer; later becoming dark grayish green and finally dark grayish brown and somewhat mouse-colored. Mature pycnidia form about the sides of the flask in about one month. Pycnidia in culture are incomplete, consisting of dense, dark pulvinate masses depressed at center where pycnospores are borne, and somewhat overgrown by loose hyphae from about the margin. Growth on corn-meal agar similar, but pycnidial production sparse, most frequently occurring about berry tissue from which culture is made.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Massachusetts, New Jersey, Wisconsin, Oregon, and Washington.

Pathological relations.—A rather common cause of storage rot of cranberries in all cranberry sections.

Ceuthospora lanata Shear, 1907 (60, p. 312)

Pycnidia.—Scattered, depressed-pulvinate, slightly erumpent, 200-375 μ in diameter, irregularly chambered within and bearing a single prominent ostiole, walls subcoriaceous, irregular in thickness; sporogenous hyphae form a dense,



Diseases of cranberry vines: A and B, Tip blight caused by *Sclerotinia oryzae*; C, rose bloom caused by *Exobasidium oryzae*; D, red leaf spot caused by *Exobasidium vaccinii*

compact, intricate layer, ultimate divisions of which are somewhat dichotomous and bear the short, elliptic, inequilateral or slightly curved, simple, hyaline spores, which are 7-9 by 3-3.5 μ . (Fig. 9.)

Type specimen.—No. 1488, C. L. S., on fallen leaves from vines of *Vaccinium macrocarpon* which had been cut and piled on the margin of a cranberry bog near Whitesville, N. J., September 2, 1904; also No. 1489, C. L. S., on leaves of dead vines, Warcham, Mass., September, 1902.

Hosts.—*Vaccinium macrocarpon*, *V. brachycera*.

Geographical distribution.—Massachusetts, New Jersey, Wisconsin, Oregon, and Washington.

Pathological relations.—The cause of black rot of cranberry. Principally a storage rot, more important in the Pacific coast and Wisconsin districts than elsewhere.

Pestalozzia guepini vacciniil Shear, 1902
(58, p. 456-457)

SYNONYM:

Pestalotia vacciniil (Shear) Guba, 1929
(29, p. 201).

Acervuli.—Subepidermal, becoming erumpent, sparsely scattered over leaf, 100-250 μ ; conidia elliptical, somewhat inequilateral, usually 4-septate, 21-25 by 5.5-6.0 μ ; 3 central cells dark colored, usually guttulate; septum below the upper cell usually darker than others; 2 terminal cells hyaline, apical 1 with 3 or 4 filiform setae, 22-35 μ long, basal cell with hyaline appendage 6-12 μ long. (Fig. 10.)

As the fungus matures the epidermis ruptures, and the spores collect in dark masses or spread out and form a thin layer about the acervuli.

Type specimen.—No. 1146, on dead leaves of *Vaccinium macrocarpon* kept in a moist chamber in a laboratory for about a week. Collected at Parkdale, N. J., by C. L. Shear.

Cultural characters.—Grows readily on corn-meal agar. Mycelium thin, white, at length becoming dense and fluffy around edges of agar and on sides of test tube. Older cultures slightly tinged with pinkish yellow color. A few conspicuous black masses of spores exuded on surface of agar within 15 days at room temperature.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—On dead leaves or isolated from fruit of cranberry, Massachusetts, New York, New Jersey, West Virginia, Wisconsin, Oregon, and Washington.

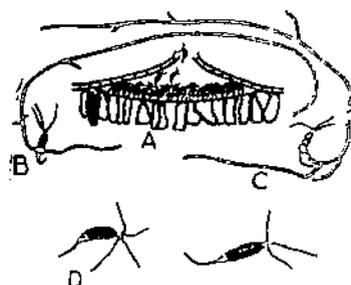


FIGURE 10.—*Pestalozzia guepini vacciniil*: A, Acervulus, $\times 70$; B and C, germinating spores; D, spores, $\times 250$. After Shear (61)

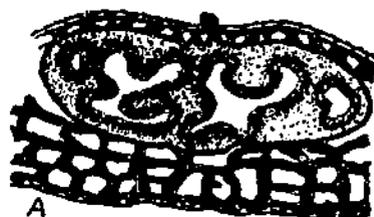
Pathological relations.—An occasional cause of storage rot of cranberry in all cranberry districts.

FUNGI CAUSING DISEASES OF CRANBERRY VINES

Sclerotinia oxycocci Wor., 1888 (86, p. 23-36)⁵

Conidia (*Monilia*).—Macroconidia lemoniform, continuous, hyaline, 14-34 by 8.5-28 μ , borne in simple dichotomously and trichotomously branched chains,

⁵ With the permission of E. E. Honey, the description of this fungus is taken largely from his unpublished manuscript, A Monograph of the North American Monilioid Species of *Sclerotinia*: *Monilia* Species. The photograph reproduced in Plate 2, E, is also taken from this monograph, and the illustrations in Plate 2, B and D, are from photographs furnished by Doctor Honey.



A



B

FIGURE 9.—*Ceuthospora lunata*: A, Vertical section of pseudium on cranberry leaf, $\times 125$; B, sporogenous hyphae and spores, $\times 1,500$. After Shear (61)

an indefinite number of conidia (20 to 30) composing a single chain at maturity often having small slender fusiform disjunctors between adjacent macroconidia. (Fig. 11, C.) Microconidia small, 2.5-3 μ in diameter, spherical, commonly containing a central refractive spot, arising directly or from short flask-shaped microconidiophores on ascospores, conidia, or mycelium in culture.

Ectostroma developed beneath the epidermis or cuticle on shoots (uprights) before and at the blossoming period, less commonly in the flowers, pedicels and leafstalks, commonly forming grayish masses of the conidial fructification along the swollen recurved stem of the upright during "hook" or early blossom stage of development. (Pl. 1, A and B.)

Pseudosclerotia develop within the fleshy pericarp of fully grown fruits as a result of blossom infection, when mature consisting of a more or less irregularly shaped, hollow, latticed or chitrate ectostroma which to some extent simulates the shape of the normal fruits. The pseudosclerotium commonly remains covered with the host cuticle and epidermis over winter, and consists of a black outer rind and white medulla composed of hyphae intermingled with dead host tissue, giving rise to apothecia the following or subsequent springs. (Pl. 2, A, B, D, and pl. 3, L, N.)

Apothecia.—One to several (up to six) arising from the pseudosclerotium in a mummied fruit, at maturity long slender stipitate, cupulate, 1-6 cm. in height, mummy brown to Prout's brown, becoming darker, almost black toward the lower portion of the stipe; stipe long, slender, smooth, cylindrical, tapering slightly toward base; rhizoidal tuft present, brownish black, well-developed, commonly attached all around the stipe, delicate, easily detached; disk at first closed, becoming cyathoid-infundibuliform, later patelliform or recurved, up to 1 cm. in diameter, commonly 5-9 mm., depth 3-7 mm., margin very thin (pl. 2, C, E); asci 8-spored, cylindric-clavate, 144-212 by 9.5-15.5 μ , apices rounded, opening by a pore; spores unequal in size, four functional spores large, ovoid, ellipsoid, continuous, hyaline, 12-22.5 by 6-12.5 μ and four smaller undeveloped spores which soon disintegrate; distribution of large spores with respect to small ones in the ascus irregular; large (functioning) spores commonly contain a single central refractive spot; paraphyses filiform, septate, slightly swollen toward the tip, with a brownish, slimy, resinous matrix surrounding the clavate tip. (Fig. 11, A, B.)

Type locality.—Finland (Woronin, 1888).

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos*, *V. oxycoccos intermedium*.

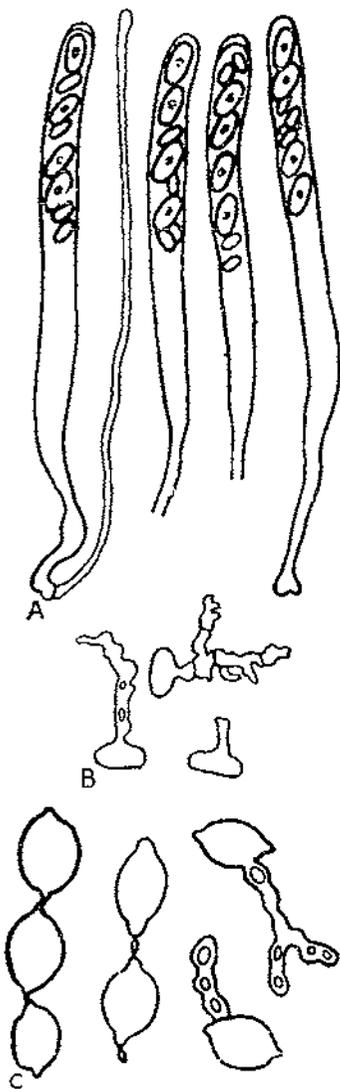
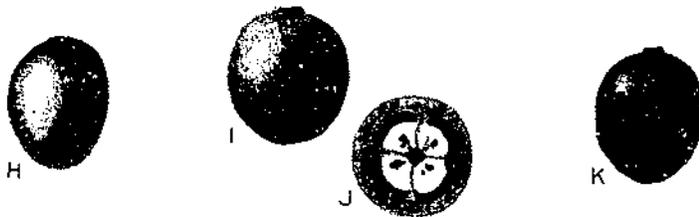
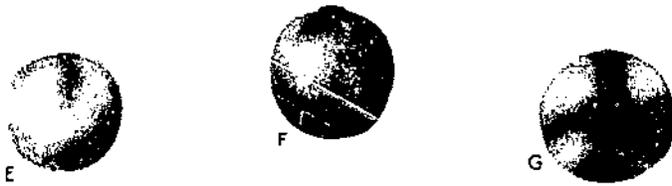
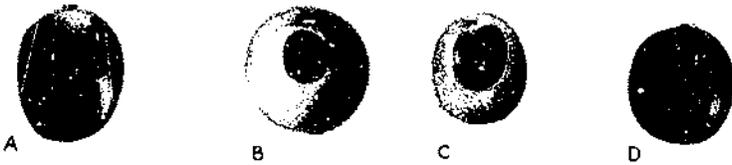


FIGURE 11. *Sclerotinia argyrea*: A, Ascus and paraphyses, $\times 440$; B, germinating ascospores, $\times 410$; C, mature conidia showing disjunctors and germinating conidia, $\times 410$.

Geographical distribution.—Maine, Wisconsin, Washington, Oregon, Finland, Denmark, Germany, Italy.

Pathological relations.—Causes tip blight of plants and hard rot or "cotton ball" disease of fruits.



Diseases of cranberry fruit: A, Early rot caused by *Gulgnardia vaccinii*; B and C, red-spot disease caused by *Exobasidium vaccinii*; D, black-spot disease caused by *Mycosphaerella nigro-maculans*; E-N, stages in the development of hard rot caused by *Sclerotinia oxycocci*

Shull



Sclerotinia oryzae on cranberry: A, Two mummified cranberries (original); B, sclerotia with berry epidermis removed (from D. E. Honey); C, apothecia, showing attachment to sclerota (original); D, cranberry upright with mummified berries attached (from Honey); E, group of apothecia in sphagnum moss (from Honey). (All natural size)



A



B

Cranberry fungi. A, *Lophodermium hypophyllum*; apothecia on cranberry leaf. $\times 4$; B, *Mycosphaerella nigro-maculans*; photomicrograph of perithecium on cranberry stem. $\times 775$

Exobasidium oxycocci Rost., 1885 (47, p. 236)

SYNONYM:

Exobasidium vaccinii (Fekl.) Wor., E. A. Burt, 1915 (11 p. 636, 649).

Mycellum stimulates axillary leaf buds to grow into short shoots with close, enlarged, distorted, pink or light rose-colored leaves; basidia elongate-clavate, superficial on affected parts, with four slender sterigmata; spores fusiform, slightly curved, hyaline, 14 by 3.5 μ , germinating soon after maturity, becoming 1-3 septate, then giving rise to one or more germ tubes producing similar but smaller conidia. (Pl. 1, C.)

Type locality.—Denmark, on *Oxycoccus palustris*.

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccus intermedium*, *Oxycoccus palustris*.

Geographical distribution.—New Hampshire, Massachusetts, Oregon, Washington, Denmark.

Pathological relations.—Causes "rose bloom" of cranberry, a disease usually of minor importance.

Exobasidium vaccinii (Fekl.) Wor., 1867
(85, p. 397-416)

SYNONYM:

Fusidium vaccinii Fekl., 1861 (26, p. 251).

Mycellum produces hypertrophied red spots on leaves; basidia similar to *Exobasidium oxycocci*; spores 14-17 by 3 μ . *E. vaccinii* and *E. oxycocci* are evidently very closely related and by some investigators (11) are regarded as forms of the same species. The two species are rarely found in the same part of a bog, and rarely if ever on the same plant. (Pl. 1, D.)

Type locality.—On *Vaccinium vitis-idaea*, Germany.

Hosts.—*Vaccinium macrocarpon* and many other ericaceous plants.

Geographical distribution.—Widely distributed in the United States and Europe.

Pathological relations.—Causes red leaf spot of cranberry, a disease of minor importance.

Mycosphaerella nigro-maculans Shear, n. sp.

Conidium.—*Ramularia nigro-maculans*, n. f. nom., grown in culture from single ascospore isolations; conidiophores ascending or erect, faint yellowish brown, branched, 2-3 μ in diameter; conidia borne in chains, faint yellowish brown when mature, globose to elliptic, 1-celled, 2-6 by 2-3.5 μ . (Fig. 12, C.)

Perithecia.—Gregarious, minute, thickly scattered over the surface of definite black spots formed on stems, berries, and leaves, embedded, with minute papillate ostiole opening to the surface, subglobose, 60-105 μ in diameter; walls membranous, two to several cells thick, walls of outer cells thickened and black, inner walls much thinner and lighter in color (pl. 4, B); asc 8-spored, borne on a thick pulvinate mass of hyaline, pseudoparenchymatous tissue at base of perithecium, sessile, cylindrical, often somewhat curved, 23-35 by 3-4.5 μ ; paraphyses none; ascospores uniseriate or irregularly biseriolate, hyaline, nearly equally 2-celled, constricted at the septum, upper cell of slightly greater diameter, long ellipsoid, 7.5-10 by 1.75-4 μ . (Fig. 12, A, B.)

Immature perithecia appear in profusion early in the fall on the black stem and berry lesions and remain dormant until spring. Ascogenous fructifications have not been found on berries, but were readily obtained by collecting diseased vines from the bogs in January, February, and March (in Oregon) and placing them in damp chambers at room temperature for a short time.

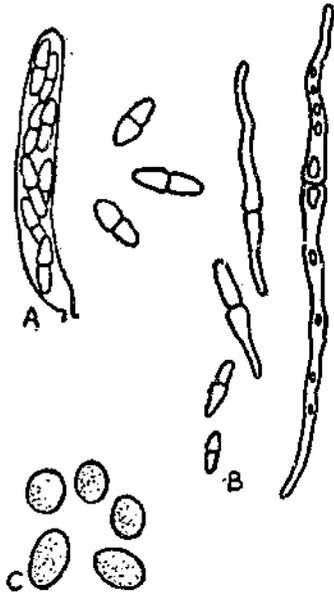


FIGURE 12.—*Mycosphaerella nigro-maculans*: A, Ascus and ascospores, $\times 1,025$; B, germinating ascospores, $\times 650$; C, conidia, $\times 1,300$

Mycosphaerella nigro-maculans is apparently very closely related to *M. punctiformis* (Pers.) Schroet. (53, p. 333), from which it differs in its slightly narrower asci and ascospores, perithecia confined to distinct black spots on the host, in its parasitic habit, and in its host. A *Ramularia*, *R. multiplex* Pk. (38, p. 99), was described from leaves of *Vaccinium oxycoccos* from New York. An examination of the type of this species, however, shows it to be different from the conidial form of this *Mycosphaerella*. The sporophores are hyaline, much longer and scarcely branched, and the conidia are hyaline and much more variable in length.

Type specimen.—Oregon, in mycological collections, Bureau of Plant Industry.

Cultural characters.—Growth on corn-meal agar grayish at first, soon becoming dark brown, spreading very slowly by radiating strands of dense hyphae. Mycelium mostly embedded in agar, but a slight, loose aerial growth containing conidiophores soon appears above the submerged mycelial strands.

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos intermedium*.

Geographical distribution.—Maine, Massachusetts, Wisconsin, Oregon, and Washington.

Pathological relations.—Consistently associated with the black-spot disease of cranberry fruits and stems and thought to be the cause.

Synchytrium vaccinii Thomas, 1880 (84, p. 279)

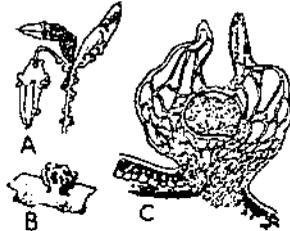


FIGURE 13.—*Synchytrium vaccinii*: A, Galls on leaves and flower bud (natural size); B, single gall; C, section through single gall, X 65. After Shear (61)

Description.—Fungus attacks leaves, young stems, flowers, and fruits, forming great numbers of small reddish gall-like swellings upon their surfaces; the fructification of the fungus is embedded near the center of these galls; the fungus consists of a scanty mycelium producing globose sporangia, 86–171 μ in diameter, with brownish, smooth walls and contents colored by chrome-yellow oil; sporangia finally develop a mass of motile swarm spores which are set free by rupture of sporangia and are distributed by water. (Fig. 13.)

Type locality.—New Jersey.

Hosts.—*Vaccinium macrocarpon*, *Gaultheria procumbens*, *Cassandra calyculata*, *Kalmia angustifolia*, *Azalea viscosa*, *Clethra alnifolia*, *Gaylussacia* sp.

Geographical distribution.—New Jersey northward to Newfoundland.

Pathological relations.—Causes red-gall disease of cranberry; of erratic occurrence.

Psilocybe agrariella Atk., var. *vaccinii* Charles,⁶ n. var.

Pileus campanulate to expanded, slightly umbonate, margin incurved at first, slightly striate, white and silky when very young, olive brown to dark mouse gray, 1–1.5 cm., hygrophanous; gills adnate, somewhat ventricose, edge whitish; stipe same color of pileus or lighter, hollow, myceloid at base, 2–3.5 cm. in length; spores in mass brown with slight purplish tinge under the microscope, high power, argus brown, subelliptical, inequilateral, 7–7.5 by 4–5 μ ; cystidia numerous, ventricose lanceolate, 40–45 by 9–11 μ .

Two species of *Psilocybe* which occur in muck, bog, or sphagnum swamps and to which the cranberry *Psilocybe* suggests relationship are *Psilocybe fuscifulva* Pk. (41) and *P. limicola* (Pk.) Sacc. (37). *P. fuscifulva* approaches this species quite closely, but is larger, the lamellae more crowded, the stem reddish brown, and the spores larger. The second species, *P. limicola*, also has crowded gills which when old are cinnamon brown in color. The general color of the pileus is dark brown.

⁶ Identification and description of this fungus by Vera K. Charles.

However, the species which this new variety most nearly approaches is *Psilocybe agrariella* Atk. (3). Through the courtesy of H. M. Fitzpatrick, of Cornell University, the writer was able to make an examination of the type material. The microscopic characters are very similar but sufficiently different to warrant a varietal distinction. The new variety has consistently smaller cystidia and spores. Microscopic differences to be observed are the less expanded pileus and olive-brown to dark mouse-gray color as contrasted with the pale reddish brown or pale rufous of *P. agrariella* Atk.

Type specimen.—In mycological collections, Bureau of Plant Industry.

Geographical distribution.—Massachusetts.

Pathological relations.—Causes "fairy ring" in cranberry bogs, a conspicuous but minor disease.

CRANBERRY FUNGI OF MINOR IMPORTANCE

ASCOMYCETES

Arachniotus trachyspermus Shear, 1902 (57, p. 133)

Conidia.—A penicilliumlike conidial form appeared in all the cultures with the perithecia, but its genetic relation has not been demonstrated by single ascospore cultures.

Perithecia.—Snowy white, consisting of slender, thin-walled, unarmed hyphae forming an anastomosing arachnoid layer about the mass of asci, 325–425 μ in diameter; asci borne upon tips of slender, scantily branched ascogenous hyphae, globose or subglobose, very thin-walled, 7–8 μ in diameter; spores ovoid, light lemon yellow in mass, echinulate-roughened, 3.25–4 by 2–2.5 μ . (Fig. 14.)

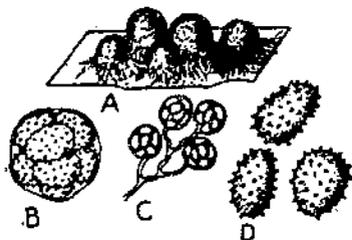


FIGURE 14.—*Arachniotus trachyspermus*: A, Perithecia on side of a culture flask, $\times 12$; B, ascus, $\times 1,500$; C, ascogenous hyphae and asci, $\times 500$; D, ascospores, $\times 2,200$. After Shear (61)

Type specimen.—No. 5798, C. L. S., in culture from decayed cranberry from Jamesburg, N. J., collected in September, 1901; slide from culture No. 115, C. L. S., from New Jersey, 1903.

Cultural characters.—First forms a fine, thin, white mycelium which is soon followed by the development of minute arachnoid snowy-white perithecia.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—New Jersey.

Pathological relations.—May cause a rot of cranberries; rare.

Gibbera compacta (Pk.) Shear, n. comb.

SYNONYMS:

Venturia compacta Pk., 1873 (38, p. 106).

Sphaeria cincinnata Schw. (not Fries), 1832 (54, p. 211).

Sphaerella maculiformis of Ricker's list, 1902 (46).

Specimens of this species collected by H. D. House on cranberry leaves in New York State were erroneously identified by Saccardo (52) as *Gibbera vaccinii* (Sow.) Fr.

Imperfect stage.—None known.

Perithecia.—Hypophyllous, usually aggregated in rather dense clusters, occasionally solitary; spines few, arranged about the ostiole, or more numerous and scattered over the upper half of perithecium, 30–60 by 6 μ ; asci usually swollen at lower end, sometimes cylindrical, 48–66 by 9–12 μ ; spores very constant in size and shape, uniseriate or crowded, uniseptate with cells generally unequal, greenish or olivaceous, 14–18 by 4–6 μ . (Fig. 15.)

Type specimen.—From Sandlake, N. Y., in New York State Museum of Natural History.

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos*.

Geographical distribution.—Nova Scotia, Maine, Massachusetts, New York, New Jersey, Wisconsin, Oregon, and Washington.

Pathological relations.—Parasitic on cranberry leaves, fruiting on lower leaf surface. Not considered particularly harmful.

Gnomonia setacea (Pers.) Ces. and de Not., 1893 (12, p. 252)

SYNONYM:

Sphaeria setacea Pers., 1794 (42, p. 25).

Perithecia.—Separate, scattered, black, membranous, depressed-globose, about 0.3-0.6 mm. in diameter, growing beneath cork layers of the bark which is penetrated by the long, slender beak; beaks

central, often 0.75-1 mm. long, about 42 μ in diameter at base, 28-30 μ above, hyaline at tip; asci 8-spored, fusiform, abruptly stipitate, apex thickened, 30-40 μ long by 6.5-10 μ broad; spores equally 2-celled, hyaline, long-fusiform, slightly constricted at the septum, often slightly curved, in fresh specimens frequently bearing a short-pointed mucilaginous appendage at either or both ends, 10-14 by 1.5-3 μ ; paraphyses lacking. Upon germinating in tap water the ascospores exhibit a remarkable degree of swelling. (Fig. 16.)

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos intermedium*, and many other deciduous species.

Geographical distribution.—Known on cranberry only from Oregon and Washington. Common in Europe and the United States on other hosts.

Pathological relations.—Saprophytic on cranberry stems.

Leptosphaeria coniothyrium (Fekl.) Sacc., 1875 (49, p. 317)

SYNONYMS:

Perithecia: *Sphaeria coniothyrium* Fekl., 1869 (27, p. 115).

Pycnidia: *Coniothyrium fockelii* Sacc., 1876 (50, p. 200).

Pycnidia.—On cranberry known only in cultures made from ascospores. Spores ovate, fuscous, 2-4 by 1.5-3 μ .

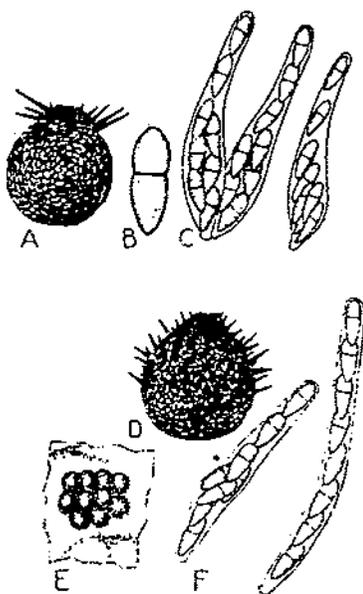


FIGURE 15.—*Gibbera compacta*: A and D, Perithecia, \times 100; B, mature 8-spored ascus, \times 900; C and F, asci, \times 625; E, group of perithecia on cranberry leaf, \times 10. After Shear (61)

Perithecia.—Single or gregarious, erumpent, depressed-globose, 300-350 μ in diameter on cranberry, papillate; asci 8-spored, cylindric, stipitate, 90-115 by 7.5-9 μ ; spores mostly uniseriate, oblong, typically 3-septate, occasionally 1 or 2 septate, more or less constricted at the septa, fuscous, 14.5-16 by 4-5 μ ; paraphyses numerous, filamentous, sometimes branched, exceeding the asci. (Fig. 17.)

Hosts.—*Vaccinium macrocarpon* and *V. corambosum* in Oregon (rare), and on a wide range of hosts in the United States and Europe.

Geographical distribution.—United States and Europe.

Pathological relations.—On cranberry saprophytic, so far as known.

Lophodermium hypophyllum (D. and H.) Shear, n. comb.

SYNONYM:

Lophodermium arceocci (Fr.) Karst. var. *hypophyllum* D. and H., 1924 (16, p. 65).

Imperfect stage.—None known.

Apothecia.—Sub-cuticular or intracuticular, ellipsoid, 500 (600) by 250-350 μ , dark colored, at maturity opening when moist by the bending outward of the walls to expose the entire hymenial layer; asci 8-spored, clavate, 60-80 by 4-5 μ , with very long stipes which usually make half or more of the entire

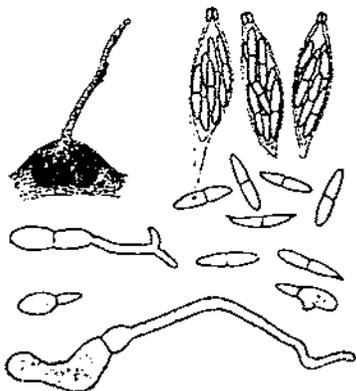
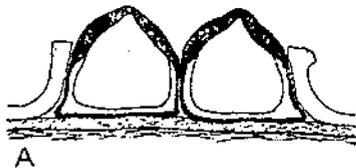


FIGURE 16.—*Gnomonia setacea*: Perithecia, \times 20; asci, ascospores, and germinating ascospores, \times 585

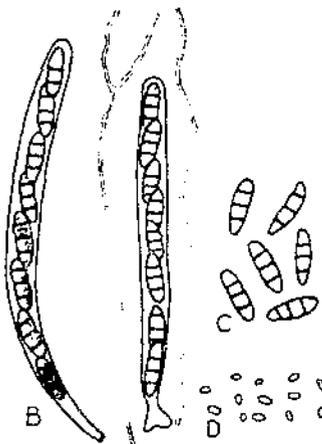
by the bending outward of the walls to expose the entire hymenial layer; asci 8-spored, clavate, 60-80 by 4-5 μ , with very long stipes which usually make half or more of the entire

ascus; paraphyses usually exceeding the asci in length and with the apex elliptical to globose; spores hyaline, straight or slightly curved at the end, 25-35 by 1-1.15 μ . (Fig. 18, A and B; pl. 4, A.)

The apothecia of this species closely resemble those of *Lophodermium oxycocci* in size and general appearance but, unlike those of *L. oxycocci* or any species of this genus which the writers have examined, when taken at the right stage of maturity will, if placed in water, open so completely as to be almost circular, with the asci and paraphyses covering the exposed surface. In opening, the side and upper walls of the apothecium bend outward, most of the movement taking place at the point where the side wall of the apothecium is least thickened, that is, where the side walls join the lower wall.



A



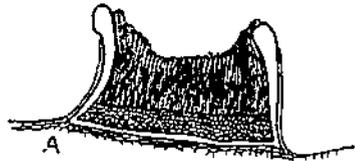
B



C

D

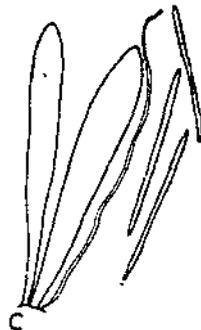
FIGURE 17.—*Leptosphaeria coniothyrium*: A, Diagrammatic section of perithecia on cranberry stem, $\times 94$; B, asci and paraphyses, $\times 470$; C, mature ascospores, $\times 470$; D, hyaline spores, $\times 470$.



A



B



C

FIGURE 18.—*Lophodermium hypophyllum*, cross section of apothecium, $\times 52$; B, *L. hypophyllum*, asci, paraphyses, and spores, $\times 450$; C, *L. oxycocci*, asci, paraphyses, and spores, $\times 450$.

This species differs from *L. oxycocci* in the peculiar slender long-stiped asci, the much shorter spores, and the nearly straight paraphyses with enlarged apex.

This fungus was originally designated as a variety of *L. oxycocci* by Dearness and House because in their material it was strictly hypophyllum. In the material examined, apothecia have been found on either surface of the leaf or on both surfaces, but examination of the material on which Dearness and House based their variety showed

other distinguishing characters which seemed to justify its elevation to specific rank.

Type specimen.—In New York State Museum of Natural History. Collected by H. D. House, Tahawus, Essex County, N. Y., August 4, 1921. Cotype material deposited in mycological collections, Bureau of Plant Industry.

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos*.

Geographical distribution.—New York, Michigan, Minnesota, Wisconsin, Oregon, and Washington.

Lophodermium oxycocci (Fr.) Karst., 1873 (54, pt. 2, p. 244)

SYNONYM:

Hysterium oxycoccus Fries, 1822 (25, p. 588).

Imperfect stage.—None known.

Apothecia.—Subcuticular or intraepidermal, ellipsoid, usually 500–600 by 250–350 μ ; dark colored, almost black, opening by a longitudinal slit; asci 8-spored, clavate, 70–90 by 8–10 μ , short stiped; spores hyaline, straight or very slightly curved, 50–60 by 4 μ ; paraphyses usually longer than asci, undulate, usually curved, and sometimes slightly thickened at the end. (Fig. 18, C.)

Specimens examined.—The description and figures of this species are taken from material gathered on *Vaccinium macrocarpon* at York, Me., August 15,

1897, by Roland Thaxter. This collection is in the Farlow Herbarium of Harvard University, and a portion of it is in the mycological collections, Bureau of Plant Industry.

Exsiccati.—The material in the following exsiccati has been examined and found to be the same:

Rehm, H. *Ascomycetes Exsiccati* 1065.

Krieger, K. W. *Fungi Saxonici Exsiccati* 2158.

Jaap, Otto. *Fungi Selecti Exsiccati* 360.

Hosts.—*Vaccinium vitis-idaea* in Europe; *V. macrocarpon* in the United States.

Geographical distribution.—Europe and New England.

Pathological relations.—Apparently saprophytic or weakly parasitic on leaves.

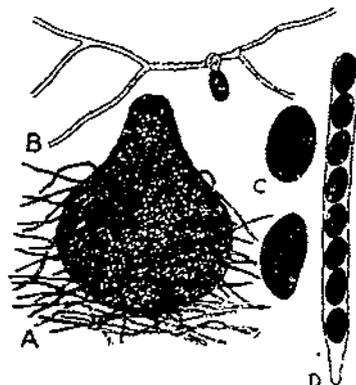


FIGURE 10.—*Melanospora destruens*: A, Perithecium, $\times 60$; B, Germinating ascospore, $\times 215$; C, mature spores, $\times 500$; D, ascus, $\times 215$. After Shear (61)

Melanospora destruens Shear, 1927 (66, p. 1024)

SYNONYM:

Anthostomella destruens Shear, 1907 (60, p. 313).

Imperfect stage.—None known.

Perithecia.—Membranous or submembranous, globose, usually somewhat contracted above into a short broad neck, ostiolate, 350–450 μ in diameter; asci 8-spored, cylindrical or cylindrical-clavate, sessile, 150–232 by 14–18 μ ; spores dark brown, elliptic, uniseriate, 16–24 by 10.5–12 μ ; paraphyses none. (Fig. 19.)

Type specimen.—Slide No. 1491, C. L. S., from pure culture No. 450 on corn meal, isolated from a diseased cranberry from New Jersey.

Cultural characters.—A white mycelial layer is first formed, soon followed by the development of black perithecia more or less overgrown by the white filaments of the mycelium.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Massachusetts, New Jersey, Wisconsin.

Pathological relations.—Infrequently causes a storage rot of cranberries.

Naevia oxycocci Dearness, in Herb.²

Imperfect stage.—Detached 1-celled hyaline conidia, 4–5 by 1–1.5 μ are often found associated with the apothecia of this fungus. So far, however, it has not been possible to demonstrate any genetic relation.

Apothecia.—Gregarious, hypophyllous, appanate, hyaline to greenish yellow, waxy, round, 0.1–0.2 mm. in diameter, subcuticular, then crumpled and sur-

²This description was prepared by Edith K. Cash.

rounded by four to five triangular fragments of the ruptured cuticle; asci clavate, rounded at the apex, short stipitate, 8-spored, 35-40 by 5-6 μ ; spores obliquely uniseriate to biseriate, oblong-fusoid, hyaline or pale greenish, straight or slightly curved, 1-septate, lower cell narrow and acute, upper wider and rounder, 6-12 by 1.5-2.5 μ ; paraphyses numerous, filiform, gelatinizing to form a yellowish epithecium. (Fig. 20.)

This species differs from *Naevia vestergrenii* Rehm (45, p. 153), the only other species reported on an ericaceous host, in its occurrence on the lower surface of the leaf, the spore septation, and the narrower spores and asci. The septate spores would place this species in the genus *Diplonaevia* Sacc., or in *Naeviella* Clements (*Phragmonaevia* subgenus *Naeviella* Rehm), which is distinguished from *Diplonaevia* by the negative iodine reaction. Although the genus *Naevia* is generally accepted as having unicellular spores, species have been described in which the spores become 1-septate.

Specimens examined.—Dearness specimen No. 4847 on *Vaccinium oxycoccos*, collected at Tahawus, Essex County, N. Y., in 1921, contains no spores. The above description is based on specimens on *V. macrocarpon* collected, respectively, by C. L. Shear at North Wakefield, N. H., July 17, 1922, and by W. A. Sawyer, jr., at Alpena, Mich., in August, 1925. These specimens have been deposited in the pathological collections of the Bureau of Plant Industry.

Hosts.—*Vaccinium macrocarpon*, *V. oxycoccos*.

Geographical distribution.—New Hampshire, New York, and Michigan.

Pathological relations.—Sometimes causes witches'-broom and death of leaves and vines.

Pezizella lythri (Desm.) Shear and Dodge, 1921 (65, p. 135-170)

SYNONYMS:

Pycnidia: *Sporonema pulvinatum* Shear, 1907 (61, p. 303). (For further synonymy see 65.)

Pycnidia.—Either epiphyllous or hypophyllous, arising from the epidermis, dark brown, pulvinate, frequently collapsing, 300-420 μ in diameter by 100-150 μ thick, chamber simple, ostiole wanting; manner of rupturing not known; spores inequilateral or slightly curved, continuous, 6-8 by 2-2.5 μ , hyaline or slightly greenish yellow in mass; sporophores simple, somewhat enlarged at the base, tapering, slightly longer than the mature spores. (Fig. 21.)

Apothecia and conidial stage (*Hainesia lythri*).—Have not been found on cranberry.

Hosts.—*Vaccinium macrocarpon* and many other plants. See Shear and Dodge, 1921 (65).

Geographical distribution.—On cranberry, Massachusetts, New Jersey, West Virginia, Oregon, and Washington.

Pathological relations.—Occasionally causes a rot of cranberries in storage.

Pseudophacidium callunae Karst., 1855 (35, p. 157)

SYNONYMS:

Phacidium callunae Karst., 1871 (34, p. 253).

Mycophacididiella callunae (Karst.) Von Hühnel, 1917 (32, p. 330).

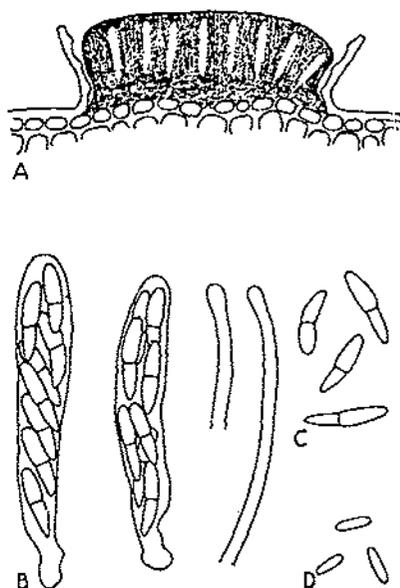


FIGURE 20.—*Naevia oxycocci*: A, Section of apothecium on cranberry leaf, \times 155; B, asci and paraphyses, \times 1,100; C, ascospores, \times 1,100; D, conidia found in association with *Naevia*, \times 1,100



FIGURE 21.—*Pezizella lythri*: A. Vertical section of pycnidium on cranberry leaf, $\times 110$; B. mature spores, $\times 1,300$; C. pycnidia on cranberry leaf, $\times 40$; D. sporophores, $\times 600$. After Shear (61)

0.2-0.3 mm. high; asci 8-spored, clavate, long stipitate, 75-120 μ long by 10-4 μ broad; spores uniseriate or often three or four crowded in upper end of ascus, 1-celled, hyaline, ellipsoid to oblong-ellipsoid, sometimes slightly curved, 7.5-15.5 by 4-6 μ , mostly 9-14 by 4-5.5 μ . (Fig. 22, A, B.)

Karsten's original description of this species does not mention paraphyses, but Rehm (44, p. 96) says "paraphyses filiform and very sparse." Von Höhnelt (32, p. 330) puts this species in his new genus *Myxophacidiella*, which, he says, has no paraphyses. On examination Krieger's European specimens cited show no signs of paraphyses, and the same is true of all the material collected by the writers in this country.

Hosts.—*Calluna vulgaris*, *Vaccinium macrocarpon*.

Geographical distribution.—Europe, Oregon, and Washington.

Genetic relationship between Pseudophacidium and Myxofusicoccum.—Single ascospore cultures of *P. callunae* made in Oregon in 1924 produced the pycnidial form only, having pycnospores identical with those of *Myxofusicoccum* on cranberry stems. Single pycnospore cultures of *Myxofusicoccum* made in 1925 gave cultures in all respects identical with ascospore cultures of *P. callunae*. The ascogenous stage has never developed in cultures from ascospores or pycnospores.

Pathological relations.—Saprophytic on cranberry stems and occasionally on leaves.

Valsa delicatula C. and E., 1877 (13, p. 19)

SYNONYM:

Perithecia: *Valsa decidua* C. and E., in Ellis and Everhart, 1892 (17, p. 465).

Pycnidia.—*Cytospora delicatula* Shear, n. f. nom. Single and scattered or sometimes two or three clustered together,

Pycnidia.—*Myxofusicoccum callunae* Shear, n. f. nom. Separate, scattered, pustular and somewhat erumpent on stems, 0.6-1.2 mm. long by 0.2-0.5 mm. wide, carbonous, irregularly chambered within, opening by one or more pores; spores hyaline, oblong, 1-celled, 5-7 by 2.5-5 μ , mostly 6-7 by 3-3.5 μ . Sections of very young pycnidia grown in culture suggest that spores are borne on very short evanescent sporophores. (Fig. 22, C.)

Apothecia.—Separate, scattered, depressed-pulvinate, erumpent, arising beneath the cork layers in the collenchyma and phloem tissues of the bark, circular or elliptic, covered by a thick purplish black excipulum until mature, then rupturing irregularly, 0.5-1.1 mm. long by 0.3-0.7 mm. wide, hypothecium about

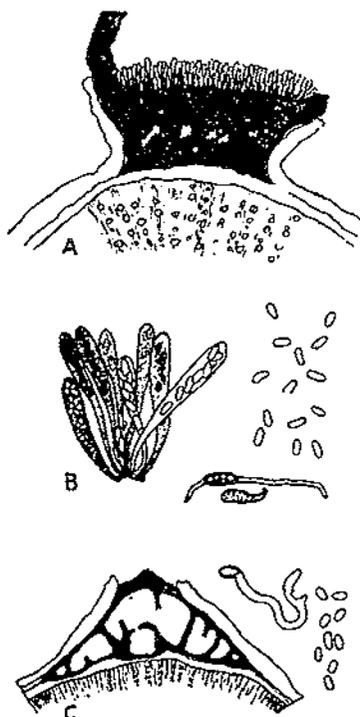


FIGURE 22.—*Pseudophacidium callunae*: A. Section of apothecium on cranberry stem, $\times 48$; B. asci and ascospores, $\times 214$; germinating ascospores, $\times 400$; C. section of pycnidium on cranberry stem, $\times 48$; pycnospores, $\times 332$; germinating pycnospore, $\times 332$

multilocular, membranous, variable in size, sometimes reaching a length of 2 mm., embedded beneath cork layer which is penetrated by the conspicuous neck; necks carbonous, variable in length, about 140 μ in diameter above, often larger at base. Conidiophores simple or semiverticillately branched and septate, fruiting branches fusiform. Conidia numerous, minute, hyaline, 1-celled, narrow, slightly curved, 4-5.5 by 0.8-1.5 μ . (Fig. 23, A, B, C, D.)

Perithecia.—Pustules small, orbicular or elongated, covered with the bark, except the minute necks which are clustered in a brown stroma; perithecia shaped like a Florence flask, membranous, the necks sometimes exceeding 1 mm. in length, slender, swollen abruptly at the apex; asci clavate, short stipitate, about 31 by 5-6 μ ; ascospores irregularly biserial, 1-celled, hyaline, sausage shaped, 7-9.5 by 2-3 μ ; paraphyses lacking. (Fig. 23, E, F, G.)

Type specimen.—Ellis, No. 2503 (2480).

Hosts.—*Andromeda* sp., *Arbutus menziesii*, *Azulca* sp., *Gaylussacia baccata*, *Leucothoe racemosa*, *Rhododendron viscosum*, *Vaccinium corymbosum*, *V. macrocarpon*, *V. pennsylvanicum*.

Geographical distribution.—Northern United States, on cranberry in Massachusetts, New Jersey, Oregon, and Washington.

Genetic relationship between Cytospora and Valsa.—Has not been proved by cultures, but by sequence in development and close association on the host.

Pathological relations.—Apparently saprophytic on cranberry stems.

Essiccati.—Ellis, North American Fungi No. 865, a and b.

Valsa delicatula C. and E.

(a) On *Andromeda racemosa*.

(b) On *Vaccinium corymbosum*.

MELAMPSORACEAE

Pucciniastrum myrtilli (Schum.) Arth., 1908
(*l.*, p. 357)

On cranberry II: Uredinia hypophyllous, scattered or somewhat gregarious, small, 0.1-0.2 mm. across, bullate, round, dehiscent by small central pore, yellowish red fading to pale yellow, long, covered by overarching epidermis; peridium hemispherical, firm, cells very small, cuboidal, wall uniformly thin, 1 μ , ostiolar cells large, ovoid, 25-35 μ high, walls smooth, uniformly thick, often nearly obliterating the lumen; urediniospores broadly obovate or ellipsoid, 13-19 by 16-24 μ ; wall colorless, thin, 1-2 μ , minutely echinulate; contents orange-yellow when fresh.

For a description of the pycnia and necia of this fungus on Tsugu and for

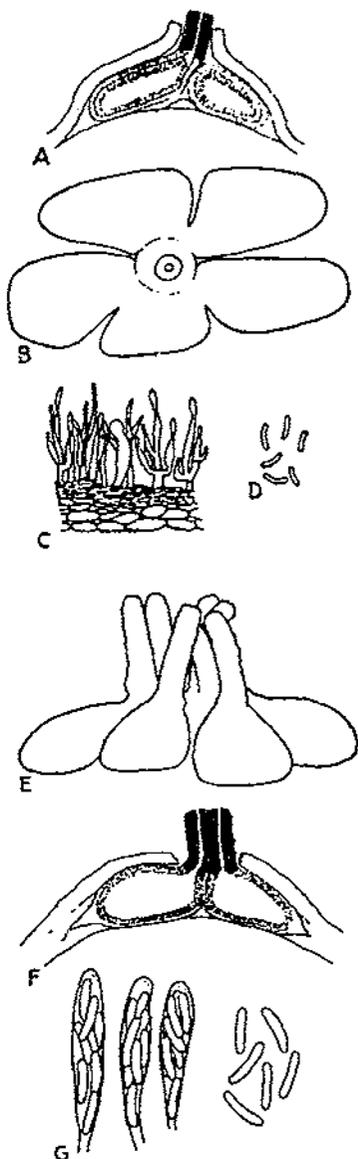


FIGURE 23.—*Valsa delicatula*, pycnidial stage: A, Section of pycnidium on cranberry stem, $\times 25$; B, outline sketch showing arrangement of locules in single pycnidium, $\times 25$; C, sporophores and section of pycnidial wall, $\times 725$; D, mature pycnospores, $\times 725$; E, sketch showing grouping of perithecia on cranberry stem, $\times 25$; F, section of perithecia on cranberry stem, $\times 25$; G, asci and mature ascospores, $\times 725$.

the synonymy, life history, hosts, and geographical range, see Arthur (2. p. 109-110, 678-679).

Pathological relations.—On cranberry known only from Pacific coast region, where it is not abundant and apparently is of little economic importance.

FUNGI IMPERFECTI

Cladosporium oxycocci Shear, 1907 (69 p. 307)

Sporophores hypophyllous, simple, septate, flexuous, yellowish brown, erect or spreading, arranged in small tufts which arise from a small, compact, sclerotoid base and are scattered over the surface of reddish-brown spots, which frequently become light colored at the center when old, 50-100 μ long; conidia aegerogenous, yellowish brown, one to three on each sporophore, cylindrical or somewhat clavate when mature, continuous or uniseptate, 15-24 by 3-4 μ . (Fig. 24.)

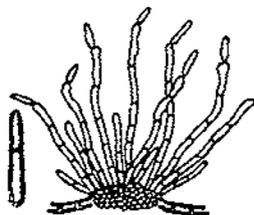


FIGURE 24.—*Cladosporium oxycocci*: A. Conidium, \times 1,300; B. conidiophores and conidia from cranberry leaf, \times 650. After Shear (81)

Type specimen.—No. 1492, C. L. S., on living leaves of *Vaccinium macrocarpon*, Arichat, Nova Scotia, June 21, 1902.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—Nova Scotia, Massachusetts, New Jersey.

Pathological relations.—Of minor importance on cranberry leaves.

Diplodia vaccinii Berl. et Roum., 1887 (10, p. 163)

Pycnidia.—On stems of cranberry, from 210-500 μ in diameter; spores 11.5-20 by 6.5-8.5 μ , mostly 13-18 by 6.5-8.5 μ , hyaline and 1-celled when very young, soon becoming septate and brown. (Fig. 25.) This species is readily distinguished from *Sphaeropsis matorum* Pk. by the very much smaller size and the septation of the pycnospores. In this characteristic, that is, the fact that the pycnospores regularly become septate as soon as they are colored rather than remaining 1-celled, *Diplodia vaccinii* resembles the form common on various deciduous hosts in the northwestern United States and in Europe, rather than *S. matorum* as found in the eastern United States. (Stevens and Shear, 82, fig. 1, d.)

Geographical distribution.—Massachusetts, New Jersey, Oregon, Washington, Europe.

No European material of this species is available for comparison, but the American material agrees well with the published description of *Diplodia vaccinii*.

Gloeosporium minus Shear, 1907 (69, p. 315)

Acervuli.—Amphigenous, subepidermal, rupturing the epidermis, small, scattered, not on a definite spot; conidia forming pale-pinkish, glutinous masses; oblong-elliptical or subcylindric, sometimes inequilateral or somewhat clavate, usually guttulate when fresh, 6-9 by 3-4 μ ; sporophores simple, slightly tapering above, one and one-half to two times the length of the conidia; no setae observed. (Fig. 26.)

Type specimen.—No. 1494, C. L. S., on fruit of the cranberry, *Vaccinium macrocarpon*, from the market, Washington, D. C., April, 1902; also on cranberry leaves from New Jersey.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—New Jersey.

Pathological relations.—Of rare occurrence, causing a storage rot of cranberries.

Helminthosporium inaequale Shear, 1907 (69, p. 307)

SYNONYMS:

For a discussion of the relationships of this fungus and suggestions as to its synonymy, see Mason, 1928 (36, p. 2-11).

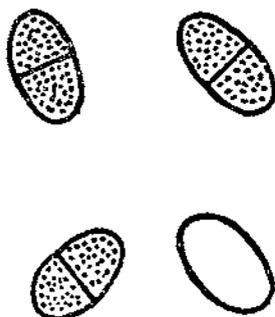


FIGURE 25.—*Diplodia vaccinii*: Pycnospores, \times 930

Description.—Sterile hyphae effuse, decumbent, much branched, dark brown, sometimes forming compact strands of 3 to 12 filaments. Fertile hyphae ascending or suberect, septate, very variable in length, 6–8 μ in diameter, bearing both terminal and lateral conidia; conidia inequilateral or curved, 3–5 celled, thick-walled, terminal cells hyaline, others deep brown in color, 22–32 by 11–14 μ , central cell usually larger than the others and swollen. Erect, slender, somewhat branching, hard, black, sclerotoid bodies are formed in abundance in old cultures. These when transplanted will produce conidia, but no other form of fructification has occurred. (Fig. 27.)

Type specimen.—Slide No. 1498, from pure culture No. 457-b, C. L. S., isolated from pulp of diseased cranberries from New Jersey, November, 1905.

Cultural characters.—On sterilized corn meal first growth nearly white, soon assuming a light smoky color, finally becoming dark smoky brown. Surface of medium covered with a thick, loose layer of much-branched hyphae. Vegetative hyphae frequently form strands of several filaments closely united.

Host.—*Vaccinium macrocarpon*, known only from cultures.

Geographical distribution.—New Jersey.

Pathological relations.—Isolated from decayed cranberry; rare.

Phyllosticta putrefaciens Shear, 1907 (60, p. 397)

Pycnidia.—Gregarious, buried or subsuperficial, globose or subglobose, membranous, dark brown or nearly black, 75–100 μ in diameter; ostiole conspicuous, surrounded by a slightly elevated, somewhat irregular margin; spores variable in shape, ovoid or ovoid-elliptic, sometimes inequilateral or slightly curved, continuous, hyaline or faintly yellowish in mass, 3.5–5 by 2.5–3 μ ; sporophores simple, very short. (Fig. 28.)

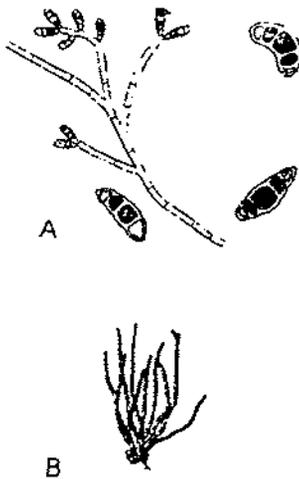


FIGURE 27.—*Helminthosporium inaequib.*: A, Fertile hyphae, \times 135, and spores, \times 400; B, sclerotoid bodies produced in old cultures, \times 5. After Shear (61)

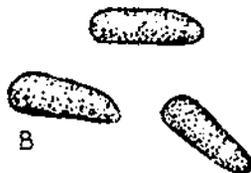


FIGURE 28.—*Phyllosticta putrefaciens*: A, Conidiophore, \times 400; B, conidia, \times 1,600. After Shear (61)

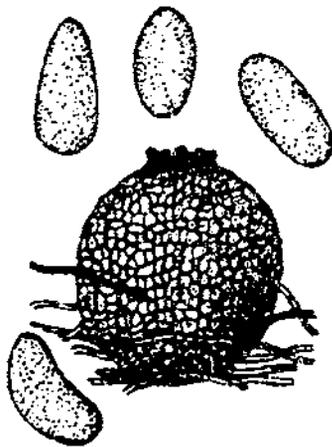


FIGURE 28.—*Phyllosticta putrefaciens*: Pycnidium, \times 160; pycnidial spores, \times 2,400. After Shear (61)

Type specimen.—Slide No. 1496 from pure culture No. 312, C. L. S., isolated from a diseased cranberry from Whitesville, N. J., September, 1905.

Cultural characters.—The fungus first produces a thin, white, floccose mycelial layer over the surface of the medium. This gradually becomes thicker and then produces a layer of black pycnidia.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—New Jersey and Massachusetts.

Pathological relations.—Causes a rot of mature cranberries; rare.

Plectothrix globosa Shear, 1902 (58, p. 457)

Evenly effuse or slightly tufted, sterile hyphae scanty, hyaline or subhyaline, septate; fertile hyphae erect, evenly scattered over the matrix or sometimes in small groups, 3-5 septate, hyaline or slightly colored toward the base, 250-350 by 3-4 μ , apex acute with three to nine short, conical, or spurlike branches, which are usually not longer than the diameter of the spores; the lower sometimes prolonged and dichotomous at the tip; conidia globose, hyaline, 15-20 μ in diameter; contents homogeneous.

Type specimen.—No. 1108, C. L. S., in mycological collections, Bureau of Plant Industry, on *Vaccinium macrocarpon* leaves collected at Parkdale, N. J. This fungus is very similar to *Eidemia acremonioides* (Harz.) Vill. and *Olpitrichum*.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—New Jersey.

Pathological relations.—Probably a saprophyte on cranberry leaves.

Rhabdozpora oxycocci Shear, 1907 (60, p. 311-312)

Pycnidia.—Usually hypophyllous, evenly distributed over surface, buried, more or less irregularly depressed-globose; slightly erumpent, greatest diameter 150-225 μ ; ostiole small, plane; wall submembranous, consisting of two layers, the inner sometimes separated from the outer, except about the ostiole, and collapsing; the epidermal cells of the host overlying the pycnidia usually

FIGURE 29.—*Rhabdozpora oxycocci*: A, Section of pycnidium on cranberry leaf, \times 130; B, sporophores and spores, \times 1,000. After Shear (61)

blackened; sporophores branched; spores hyaline, long fusiform, slightly curved, with one to three septa or pseudosepta, 20-26 by 2-3 μ . (Fig. 29.)

Type specimen.—No. 1479, C. L. S., on old leaves of *Vaccinium macrocarpon* lying on the ground under a pile of old vines, Whitesville, N. J., September 2, 1904.

Host.—*Vaccinium macrocarpon*.

Pathological relations.—As far as known occurs only on old leaves of cranberry.

Septoria sheareana Sacc. and Trotter, 1913, (51, p. 111)

SYNONYM:

Septoria longispora Shear, 1907 (60, p. 308); not Bondarz, 1906; Voglino, 1907-08; nor Miyake, 1910.

Pycnidia.—Gregarious or somewhat scattered, globose or depressed-globose, somewhat erumpent, covered by the epidermis, ostiole 150-225 μ in diameter; ostiole small; spores hyaline, filiform, curved, frequently S-shaped, sometimes pseudoseptate, 150-240 by 3-4 μ ; when straightened some are 300 μ long; sporophores simple, narrow, 6-9 μ long. (Fig. 30.)

Type specimen.—No. 1499, C. L. S., on shriveled rotten cranberries, Hunters Mills, N. J., October 14, 1902. Also on fallen cranberry leaves, No. 1500, C. L. S., same locality, June 21, 1906.

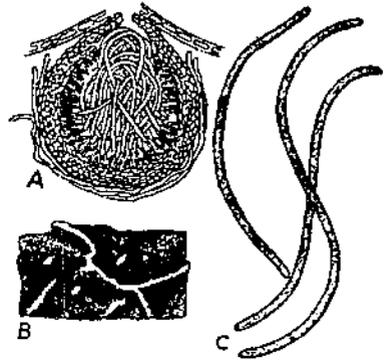


FIGURE 30.—*Septoria sheareana*: A, Section of pycnidium on cranberry leaf, \times 135; B, pycnidia on under surface, \times 35; C, mature pycnospores, \times 250. After Shear (61)

Host.—*Vaccinium macrocarpon*.
Geographical distribution.—New Jersey.

Pathological relations.—Rarely attacks cranberry fruit.

Sphaeronema pomorum Shear, 1907 (60, p. 307)

Pycnidia.—Gregarious or scattered, sub-superficial, membranous or subcoriaceous, globose or subglobose, 120-200 μ in diameter, with an ostiolate neck 75-150 μ long; spores oblong-cylindric or frequently ovoid or subelliptic, continuous, pale greenish yellow, 5-10 by 3-6 μ . (Fig. 31.)

Type specimen.—Slide No. 1495, C. L. S., from pure culture No. 141-b. Isolated from diseased cranberry, *Vaccinium macrocarpon*, Whitesville, N. J., October, 1905.

Cultural characters.—First forms a thin white layer upon the culture medium, soon followed by the development of numerous pycnidia scattered over the surface of the mycelial layer, giving it a dark appearance.

Host.—*Vaccinium macrocarpon*.

Geographical distribution.—New Jersey.

Pathological relations.—Causes a storage rot of cranberry; rare.

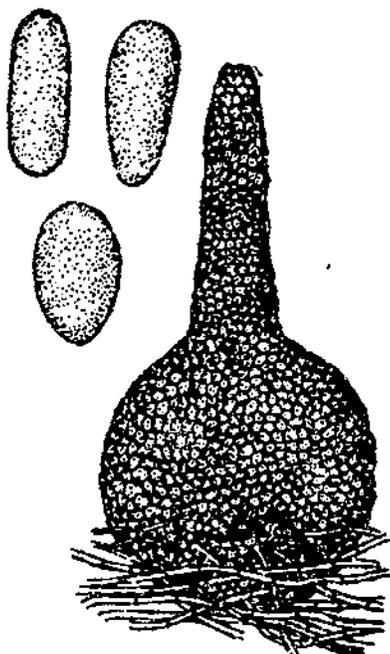


FIGURE 31.—*Sphaeronema pomorum*. Pycnidium from culture, $\times 100$, and spores, $\times 2,200$. After Shear (61)

Sphaeropsis malorum Pk.

(Pycnidial stage of *Physalospora malorum* (Pk.) Shear)

SYNONYMS:

See Shear et al. (68) and papers therein cited for a discussion of host relationships, life history, and distribution of this fungus.

Pycnidia.—Spores 10-23 by 9-11 μ ; 1-celled, brown. This fungus, which is apparently identical with *Sphaeropsis malorum* as found on numerous deciduous hosts in the eastern United States, has been collected only once on cranberry in Massachusetts. (Fig. 32.)

The perithecial stage, *Physalospora malorum*, has not been reported on the cranberry.

Strasseria oxycocci Shear, n. comb. (33, 83)

SYNONYM:

Plagiorhabdus oxycocci Shear, 1907 (60, p. 311).

Pycnidia.—Scattered, mostly hypophyllous, irregularly depressed-globose, embedded in the tissue of the host, 125-190 μ in diameter, usually very slightly erumpent with upper portion mostly covered by a thin, dark, stromatic layer consisting of the modified epidermis; wall rather thin below; interior simple, or sometimes having a few irregular chambers uniting and opening through a single ostiole which is usually rather prominent; spores hyaline or

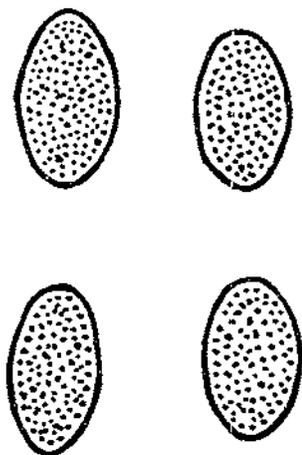


FIGURE 32.—*Sphaeropsis malorum*. Pycnosporos, $\times 930$

faintly greenish yellow in mass, slightly curved or allantoid, 8-10 by 3 μ . bearing a slender basal appendage consisting of the sporophore which is abstricted near its base; appendage 10-15 by 0.75 μ . (Fig. 33.)

Host.—*Vaccinium macrocarpon*.

Pathological relations.—Known only on dead leaves.

OTHER SPECIES

In addition to the fungi listed above, the following species, in part listed by Shear (61), have occasionally been found on cranberry:

In cultures from fruit: *Absidia* sp., *Alternaria* sp., *Aspergillus* sp., *Basisporium gailarum* Mol., *Botrytis* sp., *Chaetomium* sp., *Coremium* sp., *Dematiium* sp., *Epicoecum* sp., *Fusarium tricinctum* (?), *Fusarium* sp., *Penicillium* spp., *Phoma* sp., *Pythium* sp., *Sterigmatocystis* sp., *Stilbum* sp., *Strigosphaeria* sp., *Thielavia terricola* (G. and A.) Emmons (18).

In cultures from roots: *Gliocladium lignicolaum* Gae., *Sporonema minima*, *Trichoderma koningi* Oud.

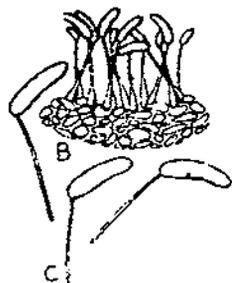
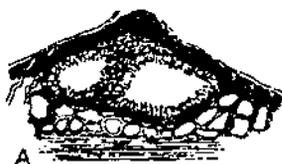


FIGURE 33.—*Striosphaeria oaxycocci*: A, Vertical section of pycnidium on cranberry leaf, $\times 375$; B, sporophores and spores, $\times 500$; C, spores with basal appendages, $\times 1,000$. After Shear (61)

In cultures from vines: *Vermicularia* sp.
On fruit: *Corticium sambuci* Fr., *Leptothyrium pomi* (Mont.) Sacc., *Papulospora* sp.

On leaves: *Chaetomium* sp., *Chondrioderma simplex* Schroet., *Discosia artoceas* (Tode) Fr., *Mycosphaeria vaccinii* (Schw.) C. and P., *Mycosphaerella vaccini* (Cke.), *Oospora* sp., *Ramularia multiplex* Pk.

The following species listed by Seymour (55) have apparently been reported by mistake.

The following have been reported through misidentification:

Sphaerella maculiformis (P. ex Fr.) Awd.
Mycosphaerella oaxycocci Dearness and House.

The following species are mentioned through errors in compilation:

Anthostoma picaceum C. and E.
Anthostomella (?) *picacea* (C. and E.) Sacc.
Sphaeria picacea C. and E.
Xylosphaeria picacea C. and F.
Guignardia bidwellii (Ell.) Viala and Ravaz.
Sphaeria cinnamata Fr.
Venturia cinnamata (Fr.) Rostr.
Sporonema epiphyllum Shear.

PHYSIOLOGY OF THE ROT FUNGI

TIME OF INFECTION

Although the fungi that are found in decayed cranberries are of greatest importance because of the storage rots that they cause, and though some of them never seem to develop in the fruit until late in the storage season, the evidence (72) indicates that infection occurs relatively early in the growing season. This is shown by Table 1, which gives the earliest dates on which various important rot fungi developed in cultures made from green cranberries in Massachusetts. It is uncertain whether the fungi here reported had actually penetrated the epidermis, but the berries placed in the culture tubes had been treated from 5 to 10 minutes in a solution of mercuric bichloride in 70 per cent alcohol and then washed in sterile distilled water.

TABLE 1.—*Earliest dates on which different fungi known to cause decay of cranberries were found in cultures of green cranberries in Massachusetts*

Name of fungus ¹	1921	1922 ²	1923	Name of fungus ¹	1921	1922 ²	1923
<i>Godronia cassandrae</i>	July 13	July 6	July 18	<i>Penicillium</i> spp.....	July 13	July 6	July 11
<i>Glomerella cingulata vaccinii</i>	July 15	July 12	.....	<i>Dematium</i> sp.....	do	do	Do.
<i>Diaporthe vaccinii</i>	Aug. 2	July 6	.....	<i>Pestalozzia guopini</i> vaccinii.....	July 10	July 12	July 19
<i>Sporonema oxycocci</i>	July 21	do	July 19	<i>Acanthorhynchus</i> vaccinii.....	July 28	.....	.....
<i>Guignardia vaccinii</i>	July 26	do	July 12	<i>Alternaria</i> sp.....	July 13	July 6	July 18

¹ See pages 43 and 44 for a list of common names of the rots caused by these fungi.

² In explanation of the difference in the time of appearance of the fungi, it should be stated that the spring of 1922 was unusually early and warm.

DISSEMINATION BY WATER

Closely related to the problem of time of infection is that of manner of dissemination of decay-producing fungi. In all probability many cranberry fungi are distributed by the wind. There is evidence, however, that the water used in reflowing bogs, especially during those reflows in which the vines are entirely submerged, as in insect control, is instrumental in carrying rot fungi. The results of cultures from cranberry tips taken before and after the June reflow on four different bogs in Massachusetts (73) are as follows: In 1922, 85 per cent of the tips taken before flooding and 67 per cent after flooding were infected; in 1923 the percentages were, respectively, 14 and 77.

That the difference between the first set of cultures and the second in both years is directly due to the effect of the flooding water seems to be proved by the fact that no such difference is found in tips taken in similar periods from bogs that were not reflowed.

ACIDITY RELATIONS

Although the acidity relations of the cranberry fungi have not been carefully studied, it has been found that all of the more important ones grow on agar media having the wide initial range of pH values 4.2 to 8.2.

A study of the effect of a rot fungus on the cranberry fruit has been made only in the case of the end-rot fungus. Stevens and Morse (81, p. 240) summarize the results of their chemical studies as follows:

The only constituent of the fruit sufficiently affected by the rot to be manifested in the chemical analysis is the total sugar. All the other changes in comparison with the sound fruit are apparently due to concentration as a corollary to the sugar consumption by the fungus.

TEMPERATURE RELATIONS *

The rates of growth of cranberry-rot fungi at different temperatures are of great interest in connection with the development of the rots they produce in storage, a subject which is considered in detail on pages 28 and 35. Figure 34 gives in graphic form the radial

* Much of the work on which the graphs in Figure 35 were based was done by F. T. Eagan.

growth of some of the more important fungi at the end of 10 days on corn-meal agar at the temperatures 0° C. (32° F.), 2.5° C. (36° F.), 5° C. (41° F.), 10° C. (50° F.), 15° C. (59° F.), 20° C. (68° F.), 25° C. (77° F.), 28° C. (82.4° F.), and 30° C. (86° F.). The graphs show that both *Godronia* and *Sporonema* are able to grow slightly at 0° and reach their maxima at about 20° and 15°, respectively, while such early rot fungi as *Acanthorhynchus*, *Glomerella*, and *Guignardia* begin growing between 2.5° and 10° and grow most rapidly at 25° or above. There is, in general, a sharp increase in the rate of growth above 10° C. (50° F.), frequently amounting to 100 per cent or more for the 5 degrees between 10° and 15°. *Godronia* is a conspicuous exception to this, its rate of growth at 10° being 60 per cent of its maximum rate.

It should be pointed out that *Acanthorhynchus* and *Guignardia* are actually of greatest importance in the warmest cranberry State (New Jersey), *Glomerella* in the warmest and second warmest (New Jersey

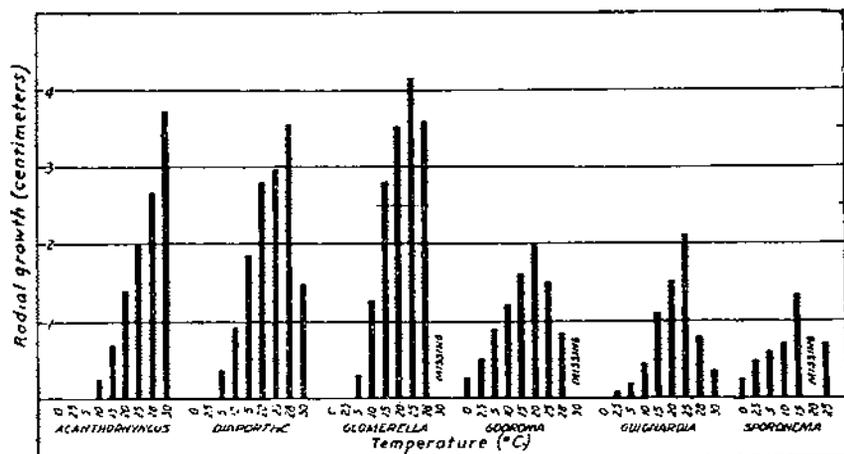


FIGURE 24.—Radial growth of the more important cranberry storage-rot fungi on corn-meal agar at the end of 10 days at temperatures ranging from 0° to 30° C. (32° to 86° F.)

and Massachusetts), while *Godronia* is notably the leading rot fungus in the colder sections (Wisconsin and the Pacific Northwest) and is of decidedly less importance in New Jersey. Again, after storage temperatures drop with the advance of the season, *Godronia* becomes strikingly the most important fungus causing rot in berries. Finally, it will be noted that 10° C. (50° F.) forms a somewhat natural temperature division, above which the so-called early rots are important causes of rot and below which *Godronia* is the principal fungus to develop in berries.

RELATIVE ABUNDANCE OF CRANBERRY FUNGI IN DIFFERENT REGIONS

The known range of each cranberry fungus is given under Taxonomy. The relative abundance of these fungi in the different cranberry regions can be intelligently discussed only with reference to the more important fungi.

FIELD ROTS

Field rots are common on cranberries only in New Jersey and on Long Island, N. Y. In Wisconsin and on the Pacific coast practically the only fungus that has been found to cause field rot is *Sclerotinia oxycocci*, and this, while occasionally locally abundant, has never exceeded a fraction of 1 per cent of the total crop for these States.

In Massachusetts field rot is met with only under exceptional circumstances. A few minor varieties such as the Middleboro usually rot somewhat on the vines, and in certain years even the standard varieties sometimes show a considerable percentage of rot. When field rot does appear in Massachusetts it is caused by the same fungi as are found in New Jersey.

In New Jersey, on the other hand, field rot appears regularly on many bogs unless they are thoroughly sprayed. A dozen samples of cranberries from different New Jersey bogs chosen at random on October 1, 1929, showed from 3 to 15 per cent rotten berries, and the amount of field rot that year was much less than the average. The more important fungi causing field rots of cranberries are *Guignardia vaccinii*, *Acanthorhynchus vaccinii*, and *Glomerella cingulata vaccinii*. Of these, *Guignardia vaccinii* is usually the most important.

RELATIVE IMPORTANCE OF DIFFERENT FUNGI AS CAUSES OF STORAGE ROTS

The relative abundance of the various cranberry rot fungi in storage is best shown by the results of comparative keeping tests made in Chicago on the crops of 1926, 1927, 1928, and 1929. As explained in the preliminary reports (77, 78, 79), the aim of this 4-year test was to discover the actual amount of rot in the cranberries from the chief growing areas that was caused by the different fungi during various periods throughout the storage season.

With minor modifications, the tests for the four years were made substantially as follows: Three or four standard packages of Howes and an equal number of McFarlin were shipped to Chicago from bogs in Massachusetts, New Jersey, and Wisconsin. In 1926 and 1927 berries from Oregon were also included. The Howes and McFarlin varieties were chosen because these are the only ones represented in all the cranberry regions.

All these lots were stored together in Chicago, and once a month a box of each was opened and 1 peck of sound berries sorted out. These sound berries were then stored in separate containers for two weeks (four weeks in 1929), after which the berries were again sorted. From the spoiled berries obtained from these lots cultures were made, and the fungi that developed were identified so far as possible.

The cranberries were held in common storage in a large cranberry warehouse in Chicago. No effort to control temperatures was made other than that usually made in such buildings; that is, the windows were left open during the warmer weather and closed when the weather became cold enough to indicate risk of freezing. Table 2 gives the approximate range of storage temperatures during the different years.

TABLE 2.—Approximate storage temperatures of cranberries at Chicago, 1926-1929

Month	1926	1927	1928	1929
	° F.	° F.	° F.	° F.
October	65-85	70-60	62-46	-----
November	53-43	58-48	55-44	55-45
December	40-30	48-35	50-40	40-30

The results of these tests should not be considered as furnishing a complete picture of the fungi found in decayed cranberries in the United States, and in particular they should not be taken as indicating the relative keeping quality of cranberries from the different regions, for no one bog can safely be taken as representative of any region. Moreover, the varieties chosen for the test were selected because they could be found in all four districts. They are, however, by no means of equal importance in all the regions. The McFarlin, for example, is of very little importance in New Jersey, and the Howes of little importance in Wisconsin and Oregon.

The results, however, apparently do furnish a satisfactory basis for comparison of the relative importance of the different rot fungi in the various regions and of the successive development of these fungi in storage. Taken together, they probably represent a larger body of information regarding storage rots of cranberries than has ever been assembled regarding storage rots of any other fruit crop.

In Figure 35 is presented in a condensed form the information that has been accumulated during the 4-year test. The height of each column represents the total spoilage up to January 1 in each lot of berries. The proportional parts of spoilage initiated by each of the five most important fungi and by sterile breakdown are represented by subdivisions of the columns. For example, 34 per cent of the berries in the 1926 sample of Wisconsin McFarlin spoiled by January 1, this spoilage being due to the following causes: Sterile breakdown, 5 per cent; *Godronia*, 25 per cent; *Acanthorhynchus*, 1 per cent; *Guignardia*, 1.5 per cent.

Taking the country as a whole, end rot (caused by *Godronia cassandrae*) exceeds all other rot fungi in importance and as a cause of spoilage is approached only by sterile breakdown.

In the Oregon berries, sterile breakdown accounts for the loss of about half of those that spoil before January 1 and *Godronia* for by far the greater portion of the other half.

Wisconsin berries differ from those from Oregon chiefly in the presence of *Guignardia* in appreciable amounts and in the fact that *Godronia* is here more important than sterile breakdown.

As regards Massachusetts berries, the results agree with those reported by Rudolph and Franklin for Howes in 1916 (48) in indicating that in this State *Glomerella* is second in importance to end rot. However, *Glomerella*, as the graphs show, is rather erratic, being important some years and almost lacking during others. In years when Massachusetts berries keep less well than usual, *Glomerella* is often abundant.

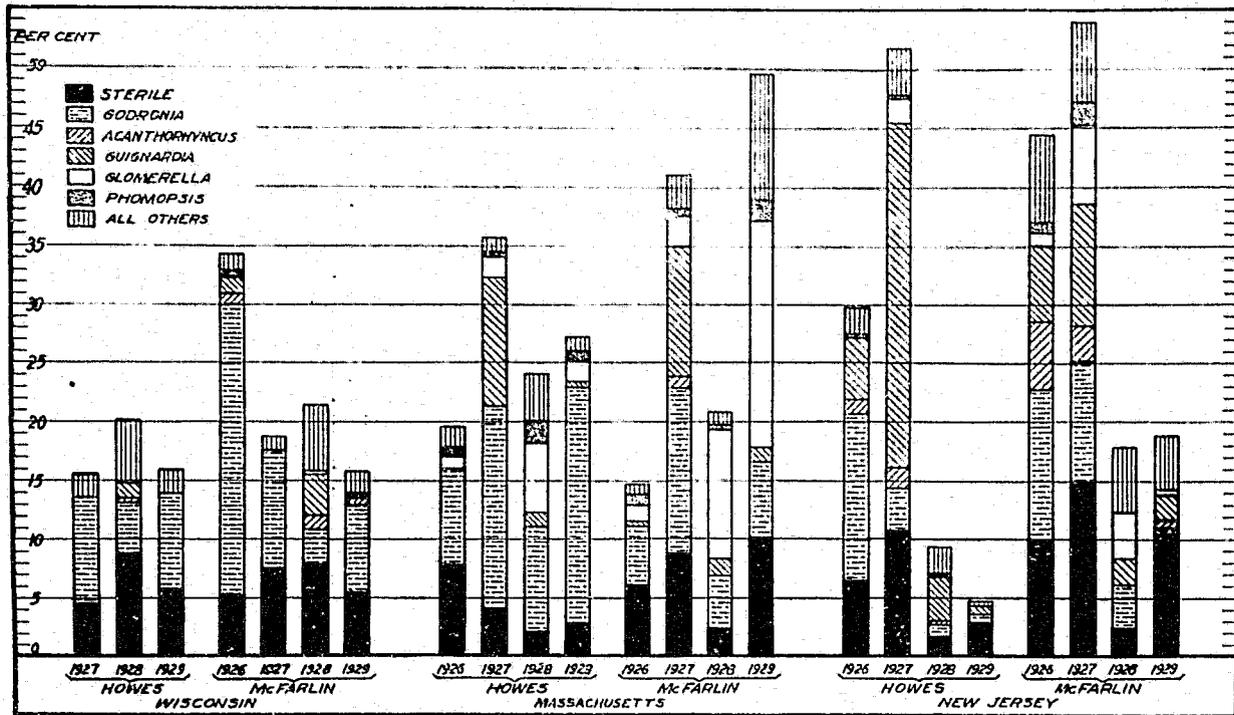


FIGURE 35.—Spoilage in Howes and McFarlin varieties of cranberries in the Chicago storage tests, 1926-1929. The total height of each column represents the percentage of spoilage in that lot on January 1, and the shaded sections represent the proportions of the total initiated by different fungi and by sterile breakdown, as indicated in the legend

New Jersey, as has been frequently pointed out, differs markedly from the other States. Here end rot assumes second place, being exceeded by *Guignardia*, long recognized as a very important cranberry fungus. The other early rot fungi, *Acanthorhynchus* and *Glomerella*, are also important.

SUCCESSION OF FUNGI IN STORAGE

The storage tests in Chicago bring out for the various cranberry-growing regions a relation shown earlier (48) for Massachusetts, namely, the succession of rot fungi through the season. Tables 3 to 6 show the frequency with which each fungus appeared in cultures from rotten berries of both varieties for all four cranberry-growing regions during every year the tests were run. The figures are expressed in terms of the percentage of all berries from which cultures were made for each lot.

TABLE 3.—Fungi present in cranberries of the *Howes* and *McFarlin* varieties from Oregon, which spoiled between dates indicated, expressed as percentage of all berries from which cultures were made

Fungus	Before Oct. 15, 1926		Oct. 15 to 31				Nov. 15 to 30				Dec. 15 to 31			
			1926		1927		1926		1927		1926		1927	
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.
<i>Acanthorhynchus vaccinii</i>		3					1						1	
<i>Alternaria</i> sp.....							1							
<i>Botrytis</i> sp.....	4		1		2	1			1	1				
<i>Ceuthospora lunata</i>	27	17	12	17	12	15			9	2				
<i>Dematium</i>														
<i>Diaporthe vaccinii</i> (<i>Phomopsis</i>).....	13	11		4		14	14		1	3				
<i>Fusarium</i> sp.....														
<i>Gloeosporium</i> sp.....														
<i>Glomerella cingulata</i> <i>vaccinii</i>														
<i>Godronia cassandrae</i> (<i>Fusicoccum putrefaciens</i>).....	15	17	48	70	31	30	26	2	54	44	8	24	32	38
<i>Guignardia vaccinii</i>					1		1		1			3	1	
<i>Penicillium</i> 29.....		6												
<i>Penicillium</i> sp.....	12	3	3		7	5		3	8	8	10		2	3
<i>Pestalotia guepini</i>					1	1				1				
<i>Sporonema oxycocci</i>					1	8			4	12			4	
Sterile.....	25	42	33	8	39	25	56	95	29	28	82	72	58	59
Unidentified.....					3	5			3	3			3	

¹ In this and succeeding tables, H. = Howes, and McF. = McFarlin.

TABLE 4.—Fungi present in cranberries of the Howes and McFarlin varieties from Wisconsin, which spoiled between dates indicated, expressed as percentage of all berries from which cultures were made

Fungi	Before Oct. 15						Oct. 15 to 31						Before Nov. 1, 1929	
	1926		1927		1928		1926		1927		1928		Before Nov. 1, 1929	
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.
Acanthorhynchus	2	1	3	6		5				10	12	12	2	2
Alternaria	5				5	1	6		5		8		4	3
Botrytis	1													
Ceuthospora							2				4			
Dematium														
Diaporthe				4	1			2					2	4
Fusarium	2	1					1							
Gloeosporium														
Glomerella														
Godronia	56	61		56	12	10	76	66	65	10	25	15	18	9
Gulgnardia				2	1	7		2	10		8	10	3	2
Penicillium 26	7			2	14		1				17			
Penicillium	21					30				7			12	3
Pestalozzia														
Sporonema			22	2									16	1
Sterile	5	14	68	4	47	28	16		20	72	25	15	46	42
Unidentified		12	8	17	12	10				2	15	9	15	13

Fungi	Nov. 15 to 30						Nov. 1 to 30, 1929	Dec. 15 to 31						Dec. 1 to 31, 1929	
	1926		1927		1928			1926		1927		1928		Dec. 1 to 31, 1929	
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	
Acanthorhynchus	6	4	2			6		8	1				1	5	
Alternaria	11		2				3	2	3				1	2	
Botrytis	2														
Ceuthospora		3				3	3							3	
Dematium															
Diaporthe		3						5			1			2	
Fusarium			2			3	10	1						3	
Gloeosporium															
Glomerella						3									
Godronia	8	78	68	56	48	39	42	23	6	56	63	7	15	65	
Gulgnardia	3	5				6		3	4	4		16	27	74	
Penicillium 26	3								2						
Penicillium	5	1	2	6	24	21		3			1	2	7	5	
Pestalozzia															
Sporonema			2					3				1		1	
Sterile	51	9	23	38	21	23	42	40	81	39	36	26	59	54	
Unidentified				6		6	6					1	10	17	

TABLE 5.—Fungi present in cranberries of the *Howes* and *McFarlin* varieties from Massachusetts, which spoiled between dates indicated, expressed as percentage of all berries from which cultures were made

Fungi	Before Oct. 15						Oct. 15 to 31						Before Nov. 1, 1926	
	1926		1927		1928		1926		1927		1928		1926	
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.
Acanthorhynchus				2						4				1
Alternaria					1									
Botrytis														
Ceuthospora														
Dematium														
Diaporthe	32	14	7	9	2			8	1	3	5	18	2	1
Fusarium							3							
Gloeosporium		8												
Glomerella			20	35	4	80	12	11	1	6	51	41	28	47
Godronia	7	22	18	14	2	12	46	36	31	28	27	4	4	3
Gulgnardia			9	9				3	57	46	5	4	7	3
Penicillium 29	11	2	2							2		18		
Penicillium						4	5						4	2
Pestalozzia			4	5								0	1	17
Sporonema			47	2						2			1	5
Sterile	21	24	25	23	4	4	29	42	4	12	6	4	7	11
Unidentified	28	24	2					3		3	5		3	3

Fungi	Nov. 15 to 30						Nov. 1 to 30, 1929		Dec. 15 to 31						Dec. 1 to 31, 1929	
	1926		1927		1928		1929		1926		1927		1928		1929	
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.
Acanthorhynchus							2									
Alternaria						1										
Botrytis							1									
Ceuthospora																
Dematium																
Diaporthe					1	3	7	8	10				2	4	6	
Fusarium															1	
Gloeosporium				1								1				
Glomerella	8	14	2	4	24	39	8	44				3	25	3		
Godronia	42	36	78	60	62	38	62	15	48	34	51	17	67	34	88	
Gulgnardia			34	8	16	7	3	2	2	5	1	1	11	15	1	
Penicillium 29			2				3					1				
Penicillium						5		1				3	3			
Pestalozzia				1	1			2					1		1	
Sporonema				1	3		3	4					1		1	
Sterile	50	20	10	17	5	7	16	26	42	50	44	78	13	20	7	
Unidentified					5	1						3		1	45	

TABLE 6.—Fungi present in cranberries of the *Howes* and *McFarlin* varieties from New Jersey, which spoiled between dates indicated, expressed as percentage of all berries from which cultures were made

Fungi	Before Oct. 15						Oct. 15 to 31						Before Nov. 1, 1929	
	1926		1927		1928		1926		1927		1928		H.	McF.
	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.	H.	McF.		
<i>Acanthorhynchus</i>	18	26	3	13	12	28	4	21	3	8		14	8	3
<i>Alternaria</i>			1	1		4		4	1					1
<i>Dematiium</i>												7		
<i>Diaporthe</i>	6	6		1	4				1	0			2	
<i>Fusarium</i>								6						
<i>Gloeosporium</i>	4													
<i>Glomerella</i>			1	23	8	31		4	6	8	3	10	1	
<i>Godronia</i>	18	3	1	3		31		2	2	15	11		3	3
<i>Guignardia</i>	12	10	69	26	15	4	41	41	77	42	58	31	23	6
<i>Penicillium 29</i>		8		1	10	12	2				3	7		11
<i>Penicillium</i>	10		3	0	15	8	11	2		3			7	
<i>Pestalozzia</i>	2		3			4			3		11	7	2	
<i>Sporonema</i>				3						3	6		4	1
<i>Sterilia</i>	20	6	16	13	23		11	14		7	6	14	42	61
<i>Unidentified</i>	8	22	3	10	4	8			3	8	3	10	7	0

Fungi	Nov. 15 to 30						Nov. 1 to 30, 1929		Dec. 15 to 31						Dec. 1 to 31, 1929	
	1926		1927		1928		H.	McF.	1926		1927		1928		H.	McF.
	H.	McF.	H.	McF.	H.	McF.			H.	McF.	H.	McF.	H.	McF.		
<i>Acanthorhynchus</i>	2	2	5	1	2	14		3			2	1	2	2		
<i>Alternaria</i>			1								3	1			5	
<i>Diaporthe</i>								4	14	5						6
<i>Gloeosporium</i>	4	2														
<i>Glomerella</i>			5	11	5	11		10						1	9	
<i>Godronia</i>	63	57	25	37	22	3	22	4	52	57	11	28	7	2	9	4
<i>Guignardia</i>	4	4	30	2	48	14	22	29	1	4	1		17	18	9	2
<i>Penicillium 29</i>								1						2		4
<i>Penicillium</i>	1			1	10	11					1					
<i>Pestalozzia</i>			5		5						1	19				
<i>Sporonema</i>				1							2	1				13
<i>Sterilia</i>	24	39	28	46	8	17	55	35	34	53	67	48	63	67	72	
<i>Unidentified</i>			2	3	2	37		10					3	10		

The same information is summarized for the seven most important fungi and for sterile breakdown in Figures 36 to 39, except that in the graphs the storage season is divided into but two periods—that before November 1 (approximately two months) and the period from November 1 to December 31. Field rot if present is included in the first period. The vertical line dividing the bars represents November 1, the solid portion of the bar the rot up to November 1, and the open portion that between November 1 and December 31. The graphs are designed to show for each region both the percentage of total spoilage and the portion of the work done by each fungus before November 1 and between November 1 and December 31.

It should be remembered that the figures in Tables 3 to 6 and in Figures 36 to 39 have no absolute value in terms of actual spoilage of berries but represent the relative abundance of the different fungi in spoiled berries. For example, there was a marked difference in amount of rot in New Jersey *Howes* in 1927 as compared with

the amount in 1928 or 1929, yet the relative proportion of rotten berries which contained the end-rot fungus was about the same in the three years, and on such graphs as these they would appear equal.

On the basis of these findings, it is evident that the cranberry fruit-rot problem in Oregon, Washington, and Wisconsin pertains chiefly to the end-rot fungus (*Godronia*). In Massachusetts the late storage rot is largely end rot, but *Guignardia* and *Diaporthe* are of appreciable importance as early rots, and *Glomerella* is the most important of the early rots. Not only is the latter fungus more

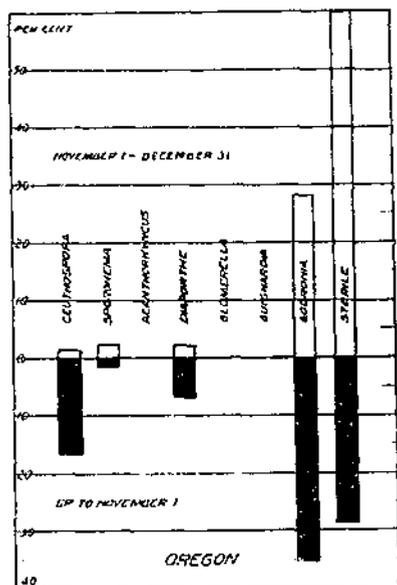


FIGURE 36.—Comparison of frequency of occurrence of fungi before and after November 1 in spoiled cranberries from Oregon. The values indicated represent, respectively, the average percentage of times each fungus developed in all cultures of Howes and McFarlin berries made prior to November 1 (solid portions of columns) in 1926 and 1927, and after November 1 (open portions of columns)

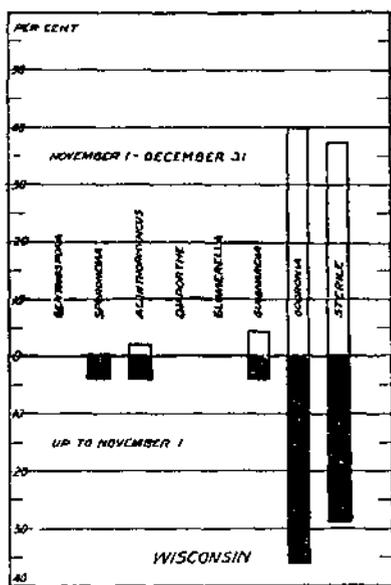


FIGURE 37.—Comparison of frequency of occurrence of fungi before and after November 1 in spoiled cranberries from Wisconsin. The values indicated represent, respectively, the average percentage of times each fungus developed in all cultures of Howes and McFarlin berries made prior to November 1 (solid portions of columns) in 1926 to 1929, inclusive, and after November 1 (open portions of columns)

important than any other early fungus in Massachusetts, but it is more important in Massachusetts than in any other State.

In New Jersey, on the other hand, while end rot is of some importance as a late rot, its supremacy is not so marked, and among the early rots it occupies a minor place. In contrast with conditions in Massachusetts, *Glomerella* occupies third place among the early rots, being exceeded by both *Guignardia* and *Acanthorhynchus*, as pointed out by Shear in 1907 (61). It should be further noted that these differences were shown by cranberries of the same varieties in the different regions.

Study of Tables 3 to 6 and Figures 36 to 39 shows that early in the storage season the dominant fungi are those that produce the

field rots, whereas in the latter half of the storage period, approximately from November 1 on, spoilage is most commonly caused by the end-rot fungus or by sterile breakdown.

CLIMATES OF DIFFERENT CRANBERRY SECTIONS IN RELATION TO ABUNDANCE OF VARIOUS FUNGI

The mean monthly temperature and precipitation for certain stations in the different cranberry regions, as published by the United States Weather Bureau, are given in Table 7. While these data, of course, do not show all the conditions under which cranberries are

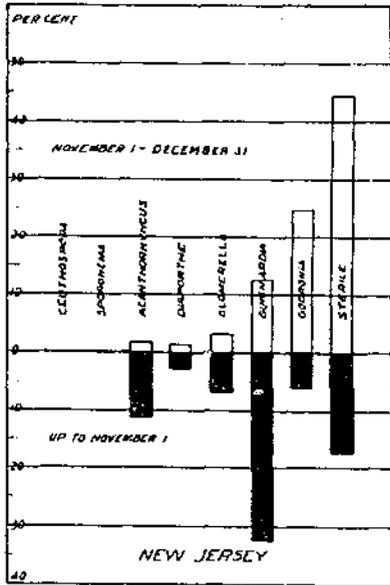


FIGURE 28.—Comparison of frequency of occurrence of fungi before and after November 1 in spoiled cranberries from New Jersey. The values indicated represent, respectively, the average percentage of times each fungus developed in all cultures of Howes and McFarlin berries made prior to November 1 (solid portions of columns) in 1926 to 1929, inclusive, and after November 1 (open portions of columns)

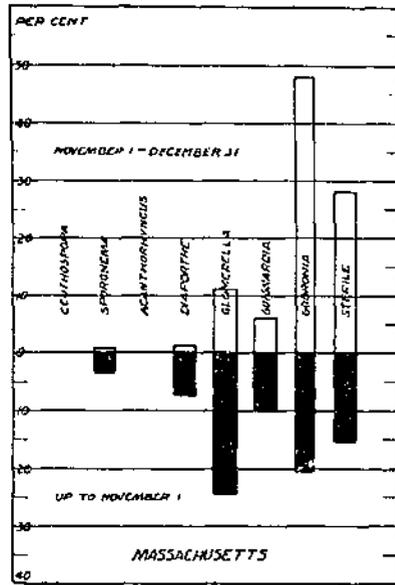


FIGURE 29.—Comparison of frequency of occurrence of fungi before and after November 1 in spoiled cranberries from Massachusetts. The values indicated represent, respectively, the average percentage of times each fungus developed in all cultures of Howes and McFarlin berries made prior to November 1 (solid portions of columns) in 1926 to 1929, inclusive, and after November 1 (open portions of columns)

grown, they give a fairly complete picture of climatic conditions in the chief centers of commercial cranberry culture in the United States. Lakewood and Indian Mills are near important cranberry areas in New Jersey. The towns of Plymouth and Wareham, Mass., have large acreages of cranberries. Wisconsin Rapids is near the largest center of cranberry culture in Wisconsin. North Head and Astoria are the nearest available stations to the cranberry-growing regions of Washington and Oregon, and while neither one actually represents conditions on the bogs themselves, the mean temperatures certainly approximate conditions on the cranberry bogs much more nearly than any others available.

TABLE 7.—*Mean monthly temperature (°F.) and precipitation (inches) for a period of years in the principal cranberry-growing regions of the United States*

[Data from reports of U. S. Weather Bureau]

TEMPERATURE

Station	Number of years recorded	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		Lakewood, N. J.	25	31.2	29.7	39.0	49.4	60.2	67.5	72.8	71.1	64.6	55.1	42.8	33.5
Indian Mills, N. J.	40	31.9	31.8	40.5	50.3	62.1	69.8	74.7	72.6	66.1	58.5	42.9	33.8
Plymouth, Mass.	40	28.3	27.3	35.2	45.0	55.4	65.1	69.4	67.1	59.5	52.2	42.0	31.5
East Wareham, Mass.	(3)	23.2	27.3	35.0	43.5	54.6	62.7	69.2	67.6	61.5	62.5	42.0	31.5
North Head, Wash.	41	42.1	43.0	45.2	47.5	50.9	54.8	57.2	57.0	60.5	62.9	48.2	41.1
Astoria, Ore.	70	40.2	42.4	45.3	49.1	52.9	57.5	60.9	61.3	58.9	53.8	47.2	42.1
Wisconsin Rapids, Wis.	31	12.7	14.7	22.9	44.4	56.2	66.1	70.2	67.8	60.5	48.1	32.0	19.9

PRECIPITATION

Station	Number of years recorded	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		Lakewood, N. J.	25	3.63	3.57	4.03	3.67	3.40	3.71	4.85	6.05	2.70	3.59	2.40	4.67
Indian Mills, N. J.	40	3.82	3.45	4.03	5.42	3.24	4.23	4.06	5.03	3.91	4.44	3.03	4.40
Plymouth, Mass.	40	4.25	4.06	4.57	4.32	3.42	3.03	3.41	3.70	3.23	3.97	4.01	4.12
East Wareham, Mass.	(3)	3.05	4.03	2.91	3.88	3.57	3.14	3.56	4.33	2.80	2.72	4.23	4.33
North Head, Wash.	41	8.78	7.45	5.66	4.14	2.95	2.28	.96	.91	2.38	4.11	7.44	8.33
Astoria, Ore.	70	12.02	9.00	6.30	5.37	3.72	2.96	1.17	1.30	3.43	5.77	11.03	11.94
Wisconsin Rapids, Wis.	31	1.35	.91	1.82	2.69	4.49	3.07	3.26	3.20	3.53	2.45	1.83	1.33

¹ The figures for East Wareham, Mass., are averages of all the data available at that point. This includes June, July, August, and September for 10 years, May and October for 18 years, and the remaining months for 3 or 4 years each.

Continued study has convinced the writers that the conditions that govern the prevalence of the end-rot fungus are, in general, in striking contrast to those that govern the prevalence of the early-rot fungi. This relation must be borne in mind not only in studying the fungi themselves but in the practical handling of the crop. Even abundant field rot apparently does not necessarily mean great loss in storage late in the season. Comparative freedom from early rots, on the other hand, is often followed by severe breakdown after November 15. In practice this amounts to a difference in the behavior of early and late varieties, but there is little to indicate that the difference is really varietal. It seems rather to relate to the time at which the berries are sold, as is plainly evidenced by those tests in which early varieties are held late for experimental purposes.

STERILE BREAKDOWN

As will be seen from the figures in Tables 3 to 6, there was in all lots a significant percentage of the spoiled berries which failed to show fungi. The death of these berries is attributed to sterile breakdown or senescence. Sterile breakdown was even more important after January 1. A detailed discussion of the factors involved in the increase and control of sterile breakdown would be out of place here, but in general it has been shown that careful handling, adequate ventilation, and sufficiently low temperatures tend to prolong the life of the cranberries as well as to retard the growth of many of the rot-producing fungi.

In general, length of frostless season is of less importance for the cranberry under cultivation than for most crops, as it is to some extent artificially regulated, sometimes by holding the flowage water late in the spring and often by reflowing to prevent injury from either late spring or early fall frosts. Cranberries come into blossom in late June or early July in Massachusetts, New Jersey, and Wisconsin, and the berries normally ripen from the first to the third week in September, according to variety, in all of these States. On the Pacific coast the blossom period is long, extending (according to variety) from the middle of June to the middle of July, and the berries mature about September 15, but in exceptional years they have been known to mature both earlier and later.

For the five months from May to September, inclusive, New Jersey is warmer and the Pacific coast markedly cooler than the others, while the mean temperatures for Massachusetts and Wisconsin are intermediate. The mean rainfall for May and September is similar in all localities. However, for the intervening months, June, July, and August, the rainfall for New Jersey is heavier and that for Oregon and Washington lighter, whereas Wisconsin and Massachusetts are again intermediate and in close agreement.

The contrasts in conditions for the period from November to March are greater. During these months the temperatures in Oregon are much warmer and the precipitation much greater than in any of the other States, whereas Wisconsin is decidedly colder and drier than the other regions. These differences to some extent influence cultural and control methods and will be discussed later.

A comparison of the temperature data just presented with what is known of the temperature relations of the fungi from their growth in pure culture shows certain very interesting correlations. On the basis of cultures made from rotted cranberries in the Pacific coast region during the years 1922 to 1925 (4), the results of which agreed with similar cultures made on Oregon berries stored at Chicago during 1926 and 1927, the four species of greatest importance in that region are shown to be *Godronia cassandrae*, *Diaporthe vaccinii*, *Sporonema oaxycocci*, and *Ceuthospora lunata*. Three of these fungi, including the end-rot fungus, which caused the destruction of well over half of all the cranberries in the storage test, show growth on culture media at 21½° or at 0° C. The fourth fungus of this group, *Diaporthe*, grows well at 5°. In contrast to the effectiveness in Washington and Oregon of cranberry fungi that grow readily at low temperatures, those fungi which have higher temperature ranges and which grow relatively little or none at 5° are rare. In this connection it may be noted that the prediction made in 1917 (71), before the fungi of the region had been carefully studied, that the problem of fungus control on the west coast would be quite different from that in the eastern part of the United States, has been abundantly fulfilled.

In New Jersey, on the other hand, the high-temperature fungi predominate, and there alone they are able to compete successfully with *Godronia cassandrae* as the cause of storage rot. Temperature is an important factor in determining the abundance of these high-temperature fungi, for, as the graphs and tables show, climatic temperatures are higher throughout the growing season in New Jersey

than in any other cranberry section. This difference is more striking if one considers only temperatures that can be efficiently utilized by such fungi as *Glomerella* and *Acanthorhyncus*. The area inclosed (71) between the 50° line and the line of mean temperature for New Jersey is approximately 50 per cent greater than the areas similarly inclosed by the lines of mean temperature for Massachusetts and Wisconsin. Even this does not fully represent the difference in favor of the high-temperature fungi.

One of the best-known methods for expressing the relative efficiency of climatic temperatures of different regions with respect to plant growth is that known as the remainder summation method; that is, a simple summation of daily mean temperatures above a zero point chosen with reference to a particular plant. In an attempt to express more nearly the actual efficiency of the temperature of the different cranberry-growing regions with respect to the growth of high-temperature fungi, remainder summation indexes have been computed for the growing season, 47° F., the minimum temperature at which *Glomerella cingulata* grows readily, being used as a zero point. These are as follows: Wisconsin Rapids, Wis., 2,371; Middleboro, Mass., 2,555; Indian Mills, N. J., 4,600; North Head, Wash., 1,896. It will be noted that the temperature efficiency index as computed for such a high-temperature fungus as *Glomerella cingulata* is practically twice as great for the New Jersey station as for either the Wisconsin or Massachusetts stations. Unquestionably this and other high-temperature fungi on an average do twice as much damage in New Jersey as in any of the other localities.

The correlation between the temperature relations of the fungi abundant in certain regions and the climatic temperatures of those regions is so striking that it seems as if there must be some direct causal connection.

RELATION BETWEEN GROWING-SEASON WEATHER AND KEEPING QUALITY OF THE CRANBERRY CROP IN MASSACHUSETTS

The rather extensive studies made during the last seven years on the relation of weather to the keeping quality of the cranberry crop in Massachusetts have been prepared for separate publication.⁹ It may be stated here, however, that no relation has yet been found in this region between rainfall during the growing season and the keeping quality of the crop. This applies both to total rain and to frequency of rainfall.

The relation that seems to exist between keeping quality of the crop and the temperature of certain critical periods is shown in Table 8. Temperature is here expressed as a simple summation of daily mean temperatures minus 50; that is, for the purpose of this study 50° F. was considered as the zero point. The estimates of keeping quality from 1912 to 1925, inclusive, are based on reports of H. S. Griffith to the New England Cranberry Sales Co., published in the annual reports of that company (28), which have been deposited in the libraries of experiment stations in all cranberry-growing States, as well as in the library of the United States Department of Agriculture.

⁹ STREYENS, N. E. WEATHER IN RELATION TO THE KEEPING QUALITY OF THE CRANBERRY CROP IN MASSACHUSETTS. Manuscript submitted to Massachusetts Agricultural Experiment Station; not yet published.

TABLE 8.—Size and keeping quality of the cranberry crop of Massachusetts and temperature summations for Wareham, Mass.

Year	Barrels	Keeping quality		Temperature summation		
		Early Black	Howes	May and June	July and August	September
1912.....	318, 000	Poor.....	Poor.....	607	1, 065	335
1913.....	333, 000	Good.....	Good.....	522	1, 152	298
1914.....	455, 000	Very poor.....	Very poor.....	625	1, 055	345
1915.....	221, 000	Fair.....	Poor.....	512	1, 094	430
1916.....	335, 000	Good.....	Good.....	520	1, 150	390
1917.....	121, 000	do.....	do.....	528	1, 287	240
1918.....	195, 000	do.....	do.....	500	1, 161	279
1919.....	390, 000	Poor.....	Poor.....	632	1, 165	364
1920.....	277, 000	Very good.....	Very good.....	451	1, 197	391
1921.....	185, 000	Fair.....	Fair.....	595	1, 132	483
1922.....	395, 000	Very poor.....	Very poor.....	770	1, 165	380
1923.....	403, 000	Good.....	Good.....	587	973	371
1924.....	300, 000	do.....	do.....	473	1, 111	303
1925.....	429, 000	do.....	do.....	638	1, 125	361
1926.....	425, 000	do.....	Poor.....	400	1, 072	275
1927.....	250, 000	do.....	Fair.....	403	1, 071	358
1928.....	335, 000	Very good.....	Very good.....	395	1, 314	342
1929.....	335, 000	Poor.....	Poor.....	646	1, 070	390

Keeping quality is the result of the interaction of many factors, such as the prevalence of rot fungi at times favorable for infection, the resistance of the cranberry to the attacks of these fungi, and the longevity of the berry itself; that is, its resistance to internal breakdown. Our knowledge of all these factors is very limited, but it is somewhat more satisfactory regarding the physiology of the fungi than regarding the physiology of the berries themselves.

In view of what is known of the temperature relations of cranberry-rot fungi, especially those that are more destructive during the early part of the season, it is obvious that high September temperatures such as those that existed in 1915 and 1921 must be unfavorable to the keeping quality of early berries.

A fairly constant relation seems to exist between the keeping quality and the climatic temperatures during May and June. (Table 8.) The Early Black was rated as having poor or very poor keeping quality every year in which the temperature summations for May and June exceeded 600, except in 1925, when the temperature was abnormally high because of a few very hot days, which did not seem to affect the crop very much. On the other hand, the very best years, 1920 and 1928, had temperature summations below 500 for these months, and in all the years in which the temperature summation for these months was below 500 the Early Black showed good keeping quality.

As regards the Howes; that is, the late berries, a high May and June temperature seems always to have been associated with poor keeping quality, but low spring temperatures were associated with poor keeping quality for the Howes in 1915 and 1926. In both these years July and August were unusually cool, as indeed they were in several of the other poor years.

So constantly are high spring temperatures and low summer temperatures associated with poor keeping quality that it seems highly probable that there must be some causal connection. At least these

relations, when taken in conjunction with incubator tests, have served during the last seven years to give a very satisfactory indication of the keeping quality of the crop.

FUNGOUS DISEASES OF THE CRANBERRY AND THEIR CONTROL

VINE DISEASES

The cranberry fungi of greatest economic importance are those that cause fruit rots. Several vine diseases caused by fungi are, however, of sufficient importance to warrant mention.

FAIRY RING

(Caused by the fungus *Psilocybe agrariella vaccinii*, p. 12, and perhaps other fungi also)

The disease here called fairy ring has long been recognized in Massachusetts and New Jersey. It is especially apt to be found on old cranberry bogs and has usually been called ringworm. While this name must be abandoned because it is misleading, it is certainly a very natural and descriptive term, as the disease in its most noticeable form causes distinct rings of dead or dying vines which are conspicuous from the upland near the bog. The first sign of the disease is a small area of dead or weak vines in a bog. Dead areas may, of course, be due to the work of insects. In the case of the fairy-ring disease, however, the area of dead vines advances outward in all directions at a rate of from 1 to 1½ feet per year. When the dead area reaches a diameter of from 4 to 6 feet the middle usually becomes "vined over" with healthy cranberry plants, thus forming the "ring."

It seems to be well established that these rings are true "fairy rings" similar to those long known in lawns and pastures and which are caused by various fungi (56). The death of the vines is caused by the dense mat of mycelium developed by the fungus. As the mycelium of the fungus advances outward, the ring increases in size, and the dying out of the fungous growth of previous years permits the cranberry vines to grow back inside the ring.

The fungus rarely fruits on the bog under natural conditions, but fruiting bodies are readily produced on sods from certain rings if the sods are kept moist and shaded. Or, if a sod is removed from the active zone in June or early July and the hole shaded and kept moist, fruiting bodies are often produced along the vertical walls.

The death of the plants is apparently due not to direct injury but to the fact that the dense mat of mycelium of the fungus cuts off the water and food supply. For this reason the injury is most evident during dry seasons and may not be noted during rainy seasons. Fairy rings are of small economic importance but attract much attention because on level bogs free from weeds they are conspicuous. The advance of rings may be stopped by ditching, and there is some indication that copper sulphate applied at the rate of 1 gallon of 5 per cent solution per square foot may stop the advance of the rings. As noted above, the effect of the disease may be largely hidden by keeping the bog wet, especially if a little fertilizer is added to the diseased area.

RED GALL

(Caused by *Synchytrium vaccinii* Thomas, p. 12)

The red gall of cranberries is a disease which once seen is very easily recognized. The disease usually appears just before the blossoms open. The buds, young leaves, and shoots become more or less covered with small, red, somewhat irregular globular galls about the size of small shot. The affected shoots produce no fruit.

Red gall is erratic in its occurrence. The cases thus far observed have appeared on a large number of plants on certain bogs during a particular season and have frequently disappeared the next season. The distribution and development of the parasite seem to depend primarily upon the water conditions of the bog and the amount and distribution of the rainfall. The spores of the fungus are adapted to distribution by water. This disease has been found thus far only in eastern cranberry bogs and most frequently in New Jersey.

No certain means of prevention is known (63), but fortunately the disease is not often of such severity as to cause concern.

ROSE BLOOM

(Caused by *Erobasiidium ozyococi*, p. 11)

The disease of cranberry plants known as rose bloom has attracted an amount of attention out of proportion to its practical importance, owing to the fact that its symptoms are so conspicuous. The disease first makes its appearance on winter-flooded bogs soon after the water has been removed in the spring. The buds in the axils of the leaves, which usually remain dormant, are attacked by the fungus, which stimulates growth. Abnormal lateral shoots bearing enlarged pink or light rose-colored leaves are the result. (Pl. 1, C.) These colored hypertrophied leaves, being somewhat crowded together, bear a superficial resemblance to a flower. This has led to the use of the common names, rose bloom and false blossom. The term "false blossom," however, should be restricted to another disease of a very different character. (See p. 43.)

Rose bloom is occasionally abundant in Washington and Oregon. It occurs to some extent almost every year in Massachusetts on plants of the Howes and Matthews varieties. This disease has been controlled by flooding the affected bog for from 36 to 40 hours when the diseased growth reaches almost full size but before spores are discharged (21, p. 192; 22, p. 108-109; 24, p. 151).

RED LEAF SPOT

(Caused by *Erobasiidium vaccinii*, p. 11)

Red leaf spot is caused by a fungus very closely related to the one producing rose bloom; in fact, some investigators regard them as merely forms of the same species. The effect upon the plant, however, is quite different. The red leaf spot produces a more or less circular spot upon the leaf and is usually bright red, especially on the upper side. (Pl. 1, D.) On the lower side the spot is paler and covered with fine spore-bearing filaments of the fungus, giving the appearance of a dense bloom or powder. Under most favorable conditions the fungus occasionally attacks the fruit, causing elevated, circular, bright red spots on green berries. (Pl. 3, B and C.) Though

the fungi producing rose bloom and red leaf spot are so closely related, the two diseases have been rarely found to occur together. Occasionally they may be found on the same bog, but rarely or never on the same plant.

Red leaf spot has been found in all cranberry-growing sections, but it usually does not cause serious injury. In general, it is most abundant under conditions of excessive moisture, whether due to fog, rain, or lack of adequate air drainage. In Washington and Oregon (4) this disease is commonly associated with black spot, described below, and the two diseases combined occasionally do serious damage.

BLACK SPOT

(Caused by *Mycosphaerella nigro-maculans*, p. 11)

Black spot is a cause of occasional damage in the Pacific Northwest. It is also sometimes found in Wisconsin and other cranberry sections, but not frequently enough to be of economic importance. As noted above, the disease often appears in association with red spot and generally occurs under conditions of excessive humidity.

Outbreaks of the disease may appear at any time during the growing season. The fungus apparently gains entrance through leaves and attacks the stems about the leaf base, forming elongated black spots that coalesce and often completely girdle the stem. Girdling is followed by defoliation and death of the portion of the plant beyond the affected part. The dead stems become thickly covered with minute black fungous fruiting bodies which produce spores the following spring. In severe cases most of the uprights in a diseased area may be killed. The same fungus occasionally attacks the fruit, causing conspicuous sunken black spots. (Pl. 3, D.)

It has been demonstrated that the disease may be controlled by repeated applications of Bordeaux mixture, but control measures other than cutting back the trees and brush surrounding the bog to facilitate air drainage are rarely warranted.

HARD ROT (COTTON BALL) AND TIP BLIGHT

(Caused by *Sclerotinia ozyococi*, p. 9)

The disease known as hard rot or cotton ball and tip blight occurs in Wisconsin and the Pacific Northwest, but has not been found in the cranberry sections of the eastern part of the United States. The tip-blight phase of the disease is unimportant as affecting the well-being of the bog, since only a very small proportion of plants is ever attacked, but the fruit-rot phase occasionally assumes serious proportions. The disease has never been known to break out over an extensive area, but is confined to small bogs or to certain parts of larger bogs where the environment apparently favors its development.

The fungus causing the disease overwinters in the form of sclerotia in mummied berries. (Pl. 2, A, B, D, and pl. 3, L, M, N.) In the spring at about the time cranberry vines start growing the sclerotia give rise to the sporulating form, which carries the infection to the current season's growth. The first symptom of the disease to be observed on the plants is the blighting of growing tips just before the blossoming period. (Pl. 1, A, B.) Affected tips wilt, dry up, turn brown, and while still attached to the vines are bent into

characteristic shapes by the development of lateral swollen areas along the dead stems. The swollen portions soon become covered with grayish powdery masses of spores, which serve to infect the fruit.

Berry infection takes place during the blossoming period. Diseased berries appear to grow normally throughout the summer, showing no external evidence of the fungus, although a white cottony mass of mycelium is developing about the seed, as may be readily seen upon cutting an infected berry. The rot begins to develop actively as the berries approach maturity. Instead of coloring up naturally, diseased berries become a more or less yellowish-white color, and instead of becoming softened, as in the case of most other fungous rots, the tissues remain rather firm and leathery, and the interior of the berry is densely packed with the white cottony fungous growth. The appearance of diseased berries at this stage is well marked and easily recognized when once seen. (Pl. 3, E-N.) Later in the season the berries shrivel somewhat, harden, and finally become mummified.

MINOR IMPORTANCE OF FIELD DISEASES CAUSED BY FUNGI

The diseases already discussed are field diseases and may fairly be classed as minor troubles. That is, while they are sometimes locally serious and often conspicuous, they have never been known to assume great commercial importance. It is doubtful if, all together, they have during any one year reduced the cranberry crop of the United States by 2 per cent.

In general, there are no cranberry diseases that cause serious injury to the plant (as distinguished from the flower and fruit) except false blossom and injuries from flooding and frost.¹⁰ This may be due in part to the fact that the cranberry occupies a position almost unique in the horticulture of the United States; that is, it is a native plant grown chiefly within its natural range and one which has never as yet been influenced by artificial crossing or, so far as is known, affected by fungi recently introduced from outside.

CRANBERRY FRUIT ROTS

From a commercial standpoint the chief problem in the control of fungous diseases of the cranberry is that of fruit rots. To the solution of this problem most of the study of cranberry diseases has been directed. It is only fair to add that, while material progress has been made both in knowledge of the diseases and in improved commercial practices, further study and experiment in this field should continue to yield valuable results.

Common names have frequently been used in the literature to designate the rots caused by specific fungi. For convenience, the names of these rots and their respective causal organisms are listed

¹⁰ The disease known as false blossom is well known to be of very great commercial importance. This disease is not caused by a fungus and is not discussed in this bulletin. Information regarding it is contained in Circular 147 (76). Injury to the cranberry plant caused by flooding water is important and is being actively investigated (9). Frost injury has long been recognized as an important cranberry problem, and the means of its control and the methods of forecasting are too highly developed to permit even a brief outline here. The work of Cox (11) on the relation between sanding and temperature is classic, and the studies of Franklin (24) in methods of forecasting minimum temperature on cranberry bogs constitute an outstanding achievement.

here End rot, caused by *Godronia cassandrae*; early rot, by *Guignardia vaccinii*; bitter rot, by *Glomerella cingulata vaccinii*; blotch rot, by *Acanthorhynchus vaccinii*; fruit rot, by *Diaporthe vaccinii*; and black rot, by *Geothospora lunata*. Three rots of this group (early, bitter, and blotch rots) characteristically develop early in the storage season or even in the field and consequently are sometimes referred to by the collective term "early rots." It should be pointed out, however, that externally most of these rots are so similar that it is impossible to distinguish them without making artificial cultures from the spoiled berries and identifying the fungi that develop in the cultures. The junior writers have examined more than 25,000 such cultures within the last 10 years. By this means knowledge of the distribution and relative abundance of the various fruit rots has been greatly increased. In discussing their control, however, it is obviously desirable to treat the storage rots as a group.

The estimate made 10 years ago that the annual loss from fruit rot averages at least 25 per cent (63) of the total crop is probably as accurate as can be made. A large part of this rot, practically all except that in New Jersey, occurs after the berries are picked.

From an economic standpoint the storage rots fall into two distinct classes—those that develop in the grower's warehouse and those that develop after the berries are shipped. Cranberries are cleaned just before they are shipped. Owing to the great efficiency of cranberry-cleaning methods, most of the berries which spoil in warehouses are removed before shipment, this loss being taken directly by the shippers. Much more serious, however, from every standpoint, is the rot that develops in berries in transit and on the market.

Berries that rot completely in the field merely reduce the crop; rots that occur while the crop is still in the grower's hands also reduce the crop and increase the cost of cleaning; rots that occur after shipping necessitate the further charges of package, freight, rejections, adjustments, remilling, and, most serious of all, the disastrous effect on the demand.

The control of fruit rots is a comprehensive problem involving many of the cultural and handling practices. Since these practices are already specialized in the different growing regions, largely in response to differences in climatic and other conditions, and since climatic conditions often place a sharp limitation on the extent to which such practices can be modified, it must be clearly understood at the outset that many of the methods discussed below are not of equal value in all sections of the country, but need to be modified in accordance with local conditions.

DIFFERENCES IN THE CRANBERRY-GROWING REGIONS WHICH ARE OF SIGNIFICANCE IN THE CONTROL OF CRANBERRY DISEASES

CLIMATIC DIFFERENCES

The chief climatic differences in the cranberry regions of the United States have already been pointed out. Obviously, differences such as these not only cause marked differences in the disease problems but influence the control methods which are practicable and profitable. The differences in summer temperatures and rainfall have been discussed. Among other factors of great importance in disease

control may be mentioned the very high rainfall in Washington and Oregon during October. In case the winter rains set in before the cranberries are harvested, they may have a marked and disastrous effect. A rainy harvest period apparently outweighs all other factors in determining the amount of rot which will occur in storage. On the other hand, the October rainfall in Wisconsin is markedly lighter than that of any other cranberry region, and if the latter half of September is also relatively dry it is possible to rake berries on water and dry them out of doors. This has been tried in other cranberry-growing regions, but has been found to promote the development of rots to a prohibitive degree.

Somewhat less obvious but nevertheless of great importance in the matter of disease control is the difference in winter temperatures. The bog soils even when not protected by water never freeze deeply on the Pacific coast. Soils in dry bogs in Massachusetts almost invariably freeze, but by far the greater number of large bogs are submerged during the winter period, and the soil rarely freezes under water. The same observations apply to New Jersey. In Wisconsin, on the other hand, bog soils nearly always freeze under the winter flowage, and often so deeply that special handling is necessary to draw the frost out of the ground early enough to permit the vines to start growing at the proper season. To accomplish this the water is removed early in the spring, and if by the middle of May it appears that the ground is not thawing rapidly enough, the water is raised again until well over the bog surface or sometimes completely submerging the vines, and is held until all frost has disappeared from the soil.

DIFFERENCES IN CULTURAL CONDITIONS

Few bogs in Oregon and Washington are provided with winter flowage. Wisconsin has no dry bogs. In New Jersey and Massachusetts the better bogs are submerged during the winter, but there are some small bogs, especially in Massachusetts, which frequently bear good crops without any winter protection.

Among other cultural differences may be noted the fact that in Massachusetts practically all of the bogs are sanded when planted and are frequently resanded. In New Jersey bogs are usually planted without sand, but some of them have been resanded. In Wisconsin bogs are, with a few exceptions, planted without sand, but some have been resanded. Oregon and Washington bogs are all planted with sand but have never been resanded.

VARIETAL DIFFERENCES

Approximately 50 per cent (6) of the cranberry crop of Massachusetts is of the variety Early Black and 35 per cent of the Howes variety. The New Jersey crop is about 30 per cent Howes (8), somewhat less than 30 per cent "native Jerseys," and about 20 per cent Early Black. In Wisconsin about 50 per cent of the acreage (5) is in native berries, about 17 per cent in McFarlin, and about 12 per cent in Searls and Bennett. In Washington and Oregon (4) the McFarlin is by far the most important variety.

DIFFERENCES IN MARKETING POLICY

Partly as a result of the differences in varieties just noted, certain differences in marketing policy have arisen which are of importance in relation to disease. During the early part of September shipments of cranberries to points throughout the country consist almost exclusively of the variety Early Black from Massachusetts and New Jersey. These berries are thus often subjected to high temperatures during shipment. The late markets throughout the country are supplied with cranberries of the Howes variety, also grown chiefly in Massachusetts and New Jersey.

In contrast to this is the situation in Wisconsin, where the berries are all marketed within a few weeks preceding Thanksgiving and largely in the central and north-central parts of the United States. Cranberries from Oregon and Washington are marketed largely in the Pacific Coast States.

CONTROL MEASURES

It has been pointed out that the various cranberry-growing regions differ so widely in certain respects that control measures valuable in one place may be unprofitable elsewhere. A somewhat comparable condition exists as regards the crops of different years in the same section. In certain seasons the keeping quality of the crop is so good that the berries will withstand careless handling and yet reach the market in salable condition, whereas in other years the berries are inherently so weak that they give trouble even if handled with considerable care. This complicates practical control in two ways. For growers to sustain losses from fruit rots in spite of care in handling tends to discouragement and to discredit careful handling methods. On the other hand, when crops are marketed advantageously in spite of lack of care in handling, the condition tends to encourage carelessness. This is particularly true after a series of crops of high keeping quality. The control measures recommended below have been found generally useful, particularly in seasons when the keeping quality is below normal.

SPRAYING

As might be expected from the fact that field rots are common in New Jersey and on Long Island, but not elsewhere, it is in New Jersey that spraying has been found to be most profitable. On the other hand, while it has been proved that spraying usually improves the keeping quality of cranberries in Massachusetts, it is very doubtful whether there is sufficient benefit to warrant the cost of spraying. In Wisconsin, as in Oregon and Washington, the keeping quality of the crop is so strongly influenced by weather conditions and handling methods that any benefit from spraying is apt to be obscured by other factors.

In the case of spraying, as in many other bog practices, it rests with the individual grower to decide on the basis of his own experience and that of neighboring growers as to whether a given practice is profitable for him. Where early rot is common, however, spraying is apparently a necessity.

Experiments conducted by the United States Department of Agriculture (59, 61) and also the experience of various growers have

demonstrated that field rots can be satisfactorily prevented and storage rots reduced by thorough spraying with 4-4-1/2-50 soap-Bordeaux mixture. This mixture should be prepared as follows:

Copper sulphate (blue vitriol or bluestone)	pounds	4
Fresh stone lime	do	4
Water	gallons	50
Commercial fish-oil soap	pound	1/2

The soap should be dissolved in about 10 gallons of water and added after the lime and bluestone have been mixed. Commercial hydrated lime may be substituted for stone lime in the above formula provided it is fresh and dry, of a floury consistency, entirely free from lumps, and if 6 pounds instead of 4 pounds are used. The soap has been found necessary in order to cause the mixture to spread and adhere to the glossy surface of the cranberry fruit and foliage. Where early rot is serious, at least four applications of Bordeaux mixture should be made during the season, 150 to 200 gallons being used to the acre. The first application should be made just before the flowers begin to open, the second when the blossoms begin to fall, the third two weeks later, and in severe cases a fourth not later than August 15, as later applications are likely to produce a staining of the fruit which may not be washed off before picking.

BOG MANAGEMENT

LATE HOLDING OF WINTER FLOWAGE

Although no controlled experiments have been made on the relation between the amount of fruit rot and late holding of winter flowage, such a relation seems to be fairly well established for Massachusetts. In that region it is usual to remove the winter-flowage water during April. In bogs planted to early varieties which are subject to early rots marked improvement in keeping quality often follows holding the winter-flowage water as late as May 15 or even June 1, one or sometimes two years out of three. These observations apply merely to Massachusetts, and the method should not be tried elsewhere without great caution.

FERTILIZER

It seems to be established that on certain soils now planted to cranberries the addition of fertilizer is necessary to produce a satisfactory yield (7). The careful studies of Franklin during the years 1911 to 1919, however, indicate that on soils which are already producing a fair commercial crop, fertilizer should be applied with great caution because of the possible increase in rot which may follow its use.

Franklin's results are given in detail in the reports of the Massachusetts Cranberry Substation for the years 1911 to 1919 and need not be repeated here. His conclusions may, however, be quoted:

The average percentages of loss in the storage tests [1916] seem to indicate that the nitrate of soda impaired the keeping quality of the fruit somewhat, while no effect in this respect connected with the use of acid phosphate and sulphate of potash is apparent [20, p. 30].

As the table shows [21, p. 223], the fruit of the fertilized areas this season [1917] was, as a rule, much inferior in both quantity and keeping quality to that of the checks, this being especially marked with the plots treated with lime

and with the maximum amount of nitrate of soda. Considering all the experience with these plots since they were started in 1911, it is the writer's judgment that, in general, whatever slight advantage in yield has been gained by the use of the fertilizers has been balanced by the cost of the treatment, the deterioration in the quality of the fruit, and the greater cost of picking due to the increased vine growth.

Table 19 [22, p. 137] gives the yields of the station fertilizer plots by years and the total yields since they were started. Considering all the experience with these plots, it seems that the advantage of any slight increase in yield that may have been caused by the fertilizers has been much more than balanced by the cost of the treatment, the deterioration in the quality of the fruit, the greater cost of picking due to the increased vine growth, and the incursion of weeds.

What the writers take to be an interesting illustration of the effect of fertilizer on the amount of rot in a New Jersey bog was brought out by the storage tests reported earlier. The New Jersey Howes (fig. 35) were taken from the same bog each year. This bog had received a heavy application of fertilizer in the summer of 1926 and a light one in the summer of 1927. No fertilizer was applied in either 1928 or 1929.

HARVESTING METHODS

By far the greater part of the cranberry crop is now harvested with scoops or rakes, although some berries are still hand picked, and more recently harvesting machines using gasoline power have come into use. The results of experiments and the experience of growers have thoroughly taught the value of harvesting berries dry and of drying them as promptly as possible if it is necessary to scoop them while still damp. The practice of harvesting berries on the water, however, which has been developed in Wisconsin and is rapidly increasing in popularity in that State, requires separate consideration.

WATER RAKING

The method of water raking consists in flooding the bog and raking off the berries as they float on or near the surface of the water. The desirability of water raking has been the subject of controversy for at least 15 years. The opponents of this method of picking believe that, in general, water-raked berries show less satisfactory keeping quality than similar berries dry raked. The proponents of the method believe that the low cost of picking, the fact that no berries are lost in the process, and the comparatively slight injury to the vines in harvesting more than outweigh any increase in storage rot which may follow this practice.

The keeping quality of water-raked berries was made the subject of a special investigation (89) from 1918 to 1920, and further studies are being made by the writers at the present time. It must be admitted that so far the results of controlled experiments which have been made chiefly with the Searls variety have shown that water raking has led to an increase in the amount of rot as compared with dry raking. This increase is admittedly greater if the berries are held late in the storage season, and it may reach serious proportions if the fruit is not dried immediately after it is harvested. Without attempting at the present time to settle any of the disputed points, it may be well to point out certain precautions which are admitted

by all careful observers to be necessary in the successful handling of water-raked berries.

If water raking is undertaken, the berries should be under water as short a time as possible, should be well colored when harvested, and should be dried as promptly as possible. Small flooding sections are a distinct advantage, as the berries under such conditions need be submerged for only a short time. The cooler the flooding water the better the chance of successful water raking. Clear spring or brook water is preferable to dark-colored swamp water. Intelligent and conscientious assistants to care for the drying of the berries are absolutely necessary if water raking is to be successfully practiced. In packing water-raked cranberries any lots which have dried slowly because of unfavorable weather or other conditions should be kept separate and marked or sold separately.

TEMPERATURE AT TIME OF PICKING

As regards the keeping quality of the berries, it would undoubtedly be better if cranberries were picked on the cooler days and in the late afternoon, very hot weather being avoided. The time when cranberries are picked, however, is determined chiefly by the practical necessity of getting the berries harvested in a relatively short time.

HANDLING METHODS

The results of careful experiments (69) extending over a series of years agree with the experience of growers that bruising, even relatively slight bruising, increases the amount of rot in a given lot of berries. The increase is, of course, greater in berries of the so-called "tender" varieties and in those lots which are most subject to decay. Because of the general recognition of this fact by growers, the practices of handling have been much modified during the last 10 or 15 years. Hand sorting of cranberries on moving belts has almost entirely replaced the older method of rolling over a wooden screen, and separating machinery has been modified to reduce injury to berries.

One very desirable change which the introduction of the method of sorting cranberries on moving belts has made possible is that the belts can be run through a small, well-lighted, and comfortably warm room, where the hand sorters work while the separating machinery at one end of the belt and the packing at the other end are both outside the room and in much lower temperatures. The berries are thus exposed to a relatively high temperature for only a fraction of a minute and do not become warmed up to any extent in the process.

A general practice, and one tending to reduce the rot following the bruising incident to sorting, is that of holding cranberries "in the chaff," just as they come from the bog, until time for shipment.

STORAGE

TEMPERATURE

Storage tests and studies of the temperature relations of the rot fungi agree in showing that the higher the temperature to which

cranberries are subjected the greater the loss from decay. The end-rot fungus, however, is able to grow somewhat even at 32° F. No facts are at hand regarding the response of the cranberry to uniform low temperatures, i. e., cold storage.

VENTILATION

Experiments given in detail in earlier papers (67, 69) show that cranberries may actually be smothered by storage in too-close containers, especially at high temperatures; also that partial smothering may result in increased loss from decay. A general recognition of these facts has been one factor leading to the adoption of ventilated one-half or one-quarter barrel boxes as the standard shipping package and to the use of ventilated boxes for storage of the fruit before it is cleaned for market.

STORAGE HOUSES

As is the case with so many cranberry problems, the construction of storage houses which will most adequately and economically meet the conditions indicated in the foregoing paragraphs vary greatly with local conditions. On the Pacific coast the most cheaply constructed building which will keep out the rain serves admirably as a warehouse. In Wisconsin, low temperatures frequently occur before the berries can be shipped and in the building of storehouses adequate provision must be made against freezing. On the other hand, since at low temperatures the respiration of cranberries, as of other fruits, is much lower, the need of special provision for ventilation is much less. In New Jersey, on the other hand, low temperatures occur only very late in the storage season, and little special provision need be made against freezing. Because of the high temperatures in September and early October, however, adequate ventilation is of first importance. Even in houses constructed without special provision for ventilation something may be accomplished by piling the boxes so as to permit as much circulation of air as possible and by keeping windows and doors open except during heavy rains or on very hot days. In Massachusetts, the designing of storehouses presents some of the problems of both Wisconsin and New Jersey. Temperatures during September are frequently high, necessitating adequate provision for ventilation. On the other hand, not infrequently there are many berries in storage in December, when low temperatures are frequently encountered, and an adequately insulated house is necessary to prevent freezing. All things considered, these needs are best met by a well-constructed house with thick walls but provided with ventilators which can be opened or closed as temperatures demand.

As already noted, a very desirable feature in the construction of any storehouse is such an arrangement as will permit the room in which the hand sorting of berries is done to be walled off from the storage space itself so that this room may be kept comfortably warm for work without raising the temperature of the berries in storage.

MARKETING THE CROP

To an extent probably unequalled by any other fruit or vegetable crop in the United States, the marketing of the cranberry crop is

purposefully controlled to reduce the losses from decay in transit and on the market.

For the long-distance shipments to western and southern points through the warm weather of September the very best berries of the Early Black variety from Massachusetts and New Jersey are selected.

The large-size (so-called "odd") varieties, many of which are known to have poorer keeping quality, are marketed chiefly during the early part of November, when the approaching Thanksgiving market guarantees their quick sale. The entire Wisconsin crop, much of which consists of large-size varieties, is sold at this time. In general, the poor or doubtful lots are sold on near-by large markets. The late market is supplied almost exclusively with the Howes, which is the last important variety to ripen.

At present the decision as to the fitness of a given lot of berries for long shipment is made by local inspectors largely on the basis of the appearance of the fruit at the time it is packed and the history of the bog. These inspectors, who have been chosen for their knowledge of cranberries and their experience in the industry, have made an enviable record for the successful handling of the problem of selection. The chief weakness of the system, as the inspectors and their associates recognize, is the variation in the keeping quality of berries from year to year and the lack of any adequate basis of comparison of different lots of berries or any satisfactory test for predicting their keeping quality. With the purpose of supplying this lack, experiments have been made to determine the keeping quality of cranberries by incubator tests. These are fully discussed in other publications (73, 74). It may be stated here, however, that, as used during the last six or seven years in Massachusetts and Wisconsin, the incubator test seems to indicate the weaker lots of fruit with a high degree of accuracy.

The canning of cranberries has increased to a considerable extent during the last few years. The chief importance of this new industry as a means of reducing losses by spoilage is in offering a profitable outlet for the disposition of fruit of excellent eating quality which is of poor carrying quality. The advantages of keeping this weak fruit off the fresh-fruit market are obvious.

One modification of earlier marketing practices which is gaining favor in Massachusetts and seems to be particularly adapted to that region is to hold any lots of early berries which show rot at picking time until the sounder lots have been shipped. Several advantages are claimed for this practice, especially the fact that it permits the weaker lots to be shipped during the cooler weather of late fall and that in many cases all the berries affected with early rot will decay completely in the storage house, permitting the packing of a much sounder lot of berries for shipment.

SUMMARY

Sixty-nine species of fungi are reported as occurring on the cranberry. Technical descriptions, supplemented in most cases by illustrations, are given for the 38 most common species. The descriptions are arranged in three groups, viz, important rot fungi (8 species), fungi causing diseases of cranberry vines (6 species), and cranberry fungi of minor importance (24 species). The remaining 31 species,

which are of infrequent occurrence, are listed as having been found, respectively, in cultures from berries, roots, and vines, on berries, and on leaves.

The physiology of the cranberry rot fungi is discussed in some detail, with special reference to time of infection, dissemination, acidity relations, temperature relations, and relative abundance of the fungi in different regions, particularly as affected by climatic conditions.

Six vine diseases caused by fungi are described, and control methods are given where these are of proved value.

Reference is made to important cranberry diseases which are of nonfungous origin.

Cranberry fruit rots, which are shown to develop principally in storage, are discussed in considerable detail. The relation which fruit-rot control bears to general cultural practices in different regions is emphasized. Control measures for the fruit rots are considered under the following headings: Spraying, bog management, harvesting methods, handling methods, storage, and marketing the crop.

SYNONYMS FOR NAMES OF HOST PLANTS

The names used in the text (and shown at the left below) are those given by the person first reporting the fungus. The synonyms given here are from Standardized Plant Names (1). Those marked "S. P. N." are standard. Those marked "Ag." are adopted by the United States Department of Agriculture.

<i>Andromeda racemosa</i>	= <i>Eubotrys racemosa</i> Ag.
<i>Cassandra calyculata</i>	= <i>Chamaedaphne calyculata</i> S. P. N.
<i>Leucothoe racemosa</i>	= <i>Eubotrys racemosa</i> Ag.
<i>Rhododendron viscosum</i>	= <i>Azalea viscosa</i> S. P. N.
<i>Vaccinium brachycera</i>	= <i>Gaylussacia brachycera</i> S. P. N.
<i>Vaccinium macrocarpon</i>	= <i>Oxycoccus macrocarpus</i> Ag.
<i>Vaccinium oxycoccus</i>	= <i>Oxycoccus palustris</i> Ag.
<i>Vaccinium pennsylvanicum</i>	= <i>Vaccinium angustifolium</i> Ag.

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