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TIP BLIGHT OF SPECIES OF ABIES CAUSED BY A NEW SPECIES OF REHMIELLOPSIS [1]

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INTRODUCTION

In 1933 a disease of the current season's growth of white, or Colorado, fir (*Abies concolor* (Gord.) Engelm.) was reported (*27*)[3] as the cause of extensive injury in a planting of about 500 trees in eastern Massachusetts and on a few ornamental trees of the same species at Augusta and Portland, Maine, and at Lake George, N. Y. The disease was attributed to *Rehmiellopsis bohemica* Bub. and Kab., which previously had been reported from Denmark (*21, 22*), Norway (*13*), Bohemia (*2*), and Scotland (*28*) on various European species of *Abies* and on the American species *A. nobilis* Lindl. Certain morphological differences, particularly in the size of the asci and spores, were noted between the fungus found in the eastern part of the United States and the species reported by European investigators. These differences were considered of sufficient importance to warrant a detailed study, with the result that the fungus occurring in this country is now described as a new species of *Rehmiellopsis*.

Because the disease was first observed in the Eastern States in ornamental plantings of white fir, it was thought that it might have been introduced into this country on horticultural material of other species of *Abies* from Europe. However, the determination of the causal fungus as a new species of *Rehmiellopsis* and the occurrence of the disease on balsam fir (*Abies balsamea* (L.) Mill.) in Maine (*26*) suggest that the fungus is native in the eastern part of the United States and may have spread from the native balsam firs to the introduced white firs used as ornamentals in New England and New York. The disease has not been found on white fir in the Western States, its native range. Preliminary surveys of areas of infection and experiments with cross infection of various species of *Abies* under natural conditions have already been reported (*26*). Additional and more conclusive data on these points are reported in this paper.

The disease varies in severity from one season to another and seems to be of relatively slight economic importance on the native balsam fir. Infection on the white firs destroys their value as ornamentals, for which they are used extensively in the eastern part of the United

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States, and has brought forth a demand by tree owners for information on control measures.

The present study includes the symptoms of the disease, the hosts and distribution, the morphology, taxonomy, and pathogenicity of the causal fungus, and the control of the disease on ornamentals.

SYMPTOMS

The earliest symptom of the disease appears on needles of the current season's growth when the bud scales begin to slough off. Several of the needles from a bud may show yellowish-pink spots on the tissue recently uncovered by the loosening bud scales. The young developing twig bearing these needles usually continues to grow, but before reaching mature size it turns dark brown or black and becomes shriveled, slightly curved, and brittle. All the needles on such a twig are affected by the fungus and change in color from light green to yellowish pink, then to dark reddish brown, and finally to gray. As the color changes and the leaf tissue dries out, the leaf margins roll backward toward the lower surface so that diseased needles appear distinctly narrower than healthy ones. They are also curved and bent out of their normal pattern of growth (fig. 1, *C*). The injury may easily be mistaken for frost injury (fig. 1, *B*), but in the latter case the reddish-brown needles appear slightly water-soaked and the growth of the young twig is immediately arrested.

It frequently happens that the twigs and needles have almost completed their development before infection takes place. In such cases most of the needles that develop later become discolored but only the tips of the twigs atrophy and die. Adventitious buds (fig. 1, *A*) may develop below the atrophied tip, producing weak, stunted needles late in the season. In many cases, however, the twigs remain uninfected and have normal terminal buds, although occasional needles or tips of needles may show characteristic color changes indicating infection. These needles usually have just attained mature size before infection, and the tissue, being soft, dries out rapidly after invasion by the fungus. The infected needles are very brittle, but most of them overwinter on the twigs for at least one season and sometimes two. On 1- and 2-year-old twigs, blackened leaf scars indicate where infected needles have broken off. On *Abies concolor* small cankers may form around leaf scars where the fungus has entered the twig tissue from an infected needle. These cankers have not been observed on *A. balsamea.*

About a month or 6 weeks after the first evidence of infection, small, black fruiting bodies are found in the tissue of the upper leaf surface, particularly along the curled leaf margins. These fruiting bodies develop very slowly during the summer, becoming slightly erumpent, but they do not reach maturity until the following spring when the new growth on the fir trees is developing. They form also on the brown, shriveled twigs and on the small cankers at the base of infected needles.

The disease appears first on the lower branches, and usually the lateral twigs of such branches are more severely affected than the terminal twigs. These laterals may be killed back to the node, while the terminal twigs may have only scattered infected needles. On seedling trees of balsam fir about 2 or 3 feet high in areas of infection in the native stands, all the needles of the new growth over

the entire tree and many of the twigs may be affected in one season. The following year the terminal buds on uninfected twigs will put out a weak, stunted growth, which, under weather conditions favor-
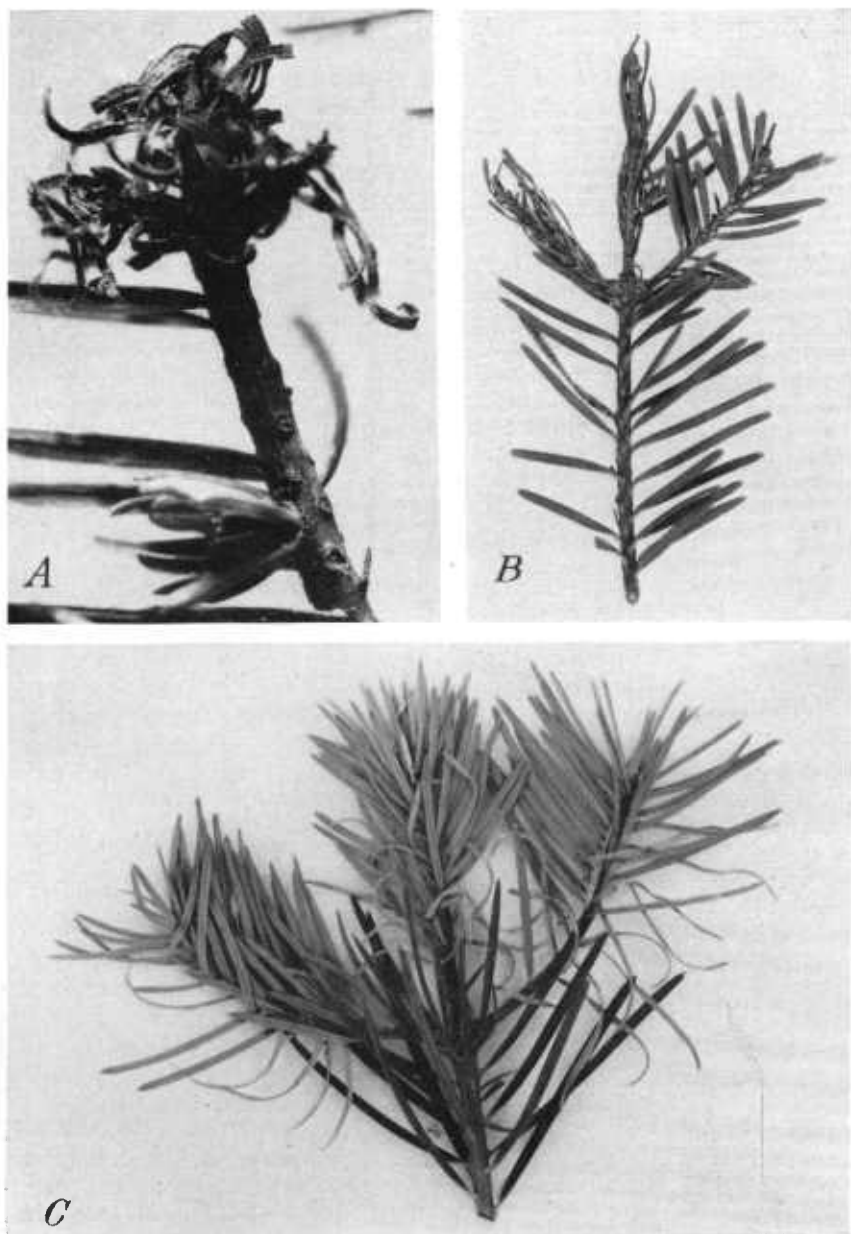

FIGURE 1.—Needles and twigs of species of *Abies* infected with *Rehmiellopsis balsameae: A, A. concolor*, twig with adventitious bud developed below infected area (approximately × 2); *B, A. balsamea*, showing dieback of young twigs (approximately × 1); *C, A. concolor*, with curled, drooping needles indicative of infection by *Rehmiellopsis balsameae* (approximately × 1).

able for the fungus, may become infected.   Severe infection repeated for several years in succession results in the death of such trees. The spread of the fungus is so largely dependent upon seasonal growth and moisture, however, that if two or three seasons of heavy infection are followed by several seasons of light infection, the trees may recover to a remarkable degree.   This is particularly true of older trees, which sometimes seem to be almost killed by the disease but exhibit a striking resumption of growth during seasons of light infection.   For this reason, in the native stands of balsam fir the disease has not yet become serious and on ornamental trees control measures can be effectively employed.

Weather conditions seem to exert an important influence on the time of infection.   In central and southern New England the spores reach maturity during the latter part of May and early June, when the buds of the white firs are normally developing.   On balsam firs in northern Maine the season of bud development and infection is slightly later, usually occurring in late June or early July.   An early growing season or one with limited rainfall results in a relatively small amount of bud and twig infection, so that only scattered needles of the new growth are injured.   A delayed, moist season, on the other hand, causes a rapid development of young succulent tissue that is particularly susceptible to infection at a time when the fungus spores are mature.   In such cases conspicuous and serious injury may occur within 2 weeks from the time that the bud scales are entirely sloughed off.

Fir trees of all sizes and ages may be affected.   White firs about 40 years old have shown infection for the past 10 years with varying degrees of severity from one year to another, depending upon weather conditions, but with no apparent decrease in susceptibility as the trees increase in age.   On native balsam firs over 30 years old, needles on all branches and on the leaders may become infected.   In contrast to this, Wilson and MacDonald (*28*), in their study of a similar disease caused by *Rehmiellopsis bohemica*, found that in Scotland large trees of *Abies alba* Mill. 50 to 80 years old were not attacked by the disease even in the vicinity of heavily infected young plantations, and E. Rostrup (*21*) stated that in Denmark trees of *A. alba* 10 to 20 years old were susceptible to the same disease but trees about 30 years old seemed to be resistant.

HOSTS AND DISTRIBUTION

In a previous report of the distribution of the disease (*26*) the writer designated the causal fungus in all cases as *Rehmiellopsis bohemica*.   The results of the present study, however, indicate that in the collections described in that report only the fungus on native *Abies lasiocarpa* (Hook.) Nutt., collected at Edgewood, British Columbia, is identical with the European species of *Rehmiellopsis*. The new species described in this paper occurs in the collections reported from native *A. balsamea* in northern Maine; from ornamental trees of *A. concolor* in southern Maine and New Hampshire, eastern Massachusetts, Rhode Island, and eastern New York; of *A. fraseri* (Pursh) Poir. and *A. nobilis* in eastern Massachusetts; and of *A. cephalonica* Loud. in Rhode Island.

Surveys in northern New England in the spring of 1940 and 1941 disclosed the presence of infected balsam firs in localities in northern

Maine additional to those already reported.[4]   The area of infection extends from Ripogenus Dam in northeastern Maine to the New Hampshire border.   Considerable infection was found also in the latter State from Colebrook to the Canadian border and just over the New Hampshire line in Vermont.   Efforts have repeatedly been made to trace the disease southward toward the coast of Maine and New Hampshire, where areas of infection on white fir are located.   Only one instance is known of the occurrence of infection on the two species of fir within a short distance of each other.   In 1940 an infected balsam fir was found by C. K. Goodling about 10 miles east of Augusta, Maine, where white firs have been infected for at least 10 years.   An inspection of other balsam firs in the region surrounding Augusta has failed to show any further evidence of infection.   Moreover, a relatively thorough inspection of native balsam firs in New York State just north of infected white firs at Lake George revealed no evidence of the disease in 1937.   It is impossible at present to account for these isolated spots of infection on white firs, but unknown sources may be located in the balsam firs on heavily wooded hills and mountains of southeastern Maine and northeastern New York.

In 1920 Faull (7) described a twig blight of balsam fir in Canada, the cause of which was then unknown.   His description of the symptoms and his illustrations, however, give every indication that the disease was similar to or identical with that on balsam fir in Maine.   Collections made by him in 1919 on Bear Island, Lake Timagami, Ontario, and in 1928 in the region of Ste. Anne des Monts, and Claude Lake, Gaspé County, Quebec, examined by the writer, showed characteristic symptoms and a few immature fruiting bodies but no spores.   Two other collections, made by G. D. Darker in 1925 and J. R. Hansbrough in 1935 on Bear Island, Lake Timagami, also had immature fruiting bodies.   All attempts to locate material from Quebec and Ontario with mature fruiting bodies have failed.   It seems probable, however, that the fungus in these regions is identical with that across the border in Maine. [5]

MORPHOLOGY OF THE CAUSAL FUNGUS

HYPHAE

In a newly infected needle, the hyphae are found first in the intercellular spaces below the stomata, but the exact method of entrance by the germ tubes has never been observed.   The hyphae advance between the mesophyll cells; as the leaf tissue gradually becomes affected by the fungus, the hyphae entirely fill the cells, even those of the vascular tissue.   The newly developing hyphae are hyaline to subhyaline, measuring 4μ to 6μ in width, increasing to 14μ, and are densely granular.   As the hyphae increase in width the walls become heavier.   In late autumn, when the fruiting bodies have formed, the older hyphae throughout the tissue gradually turn brown and develop distinctly heavy walls and conspicuous oil globules.

    [4] WATERMAN, A. M., and ALDRICH, K. F.   REHMIELLOPSIS NEEDLE BLIGHT OF BALSAM FIR IN MAINE.
U. S. Bur. Plant Indus., Plant Dis. Reptr. 24:201–205, illus.   1940.   [Processed.]
    [5] A specimen of *Abies balsamea*, collected in July 1944 by W. A. Reeks at Cape Breton Island, Nova Scotia, and referred to the writer by Mildred K. Nobles, Central Experimental Farm, Ottawa, Canada, had a few infected needles of the previous year's growth with mature spores typical of the species of *Rehmiellopsis* that occurs in Maine.

PERFECT STAGE

DEVELOPMENT OF ASCOMA

The fruiting bodies of the ascogenous stage begin to form about 4 weeks after the needles become infected. At first they are composed of more or less globoid, loosely woven masses of hyaline hyphae and lie just below the epidermis, engulfing mesophyll cells in the vicinity
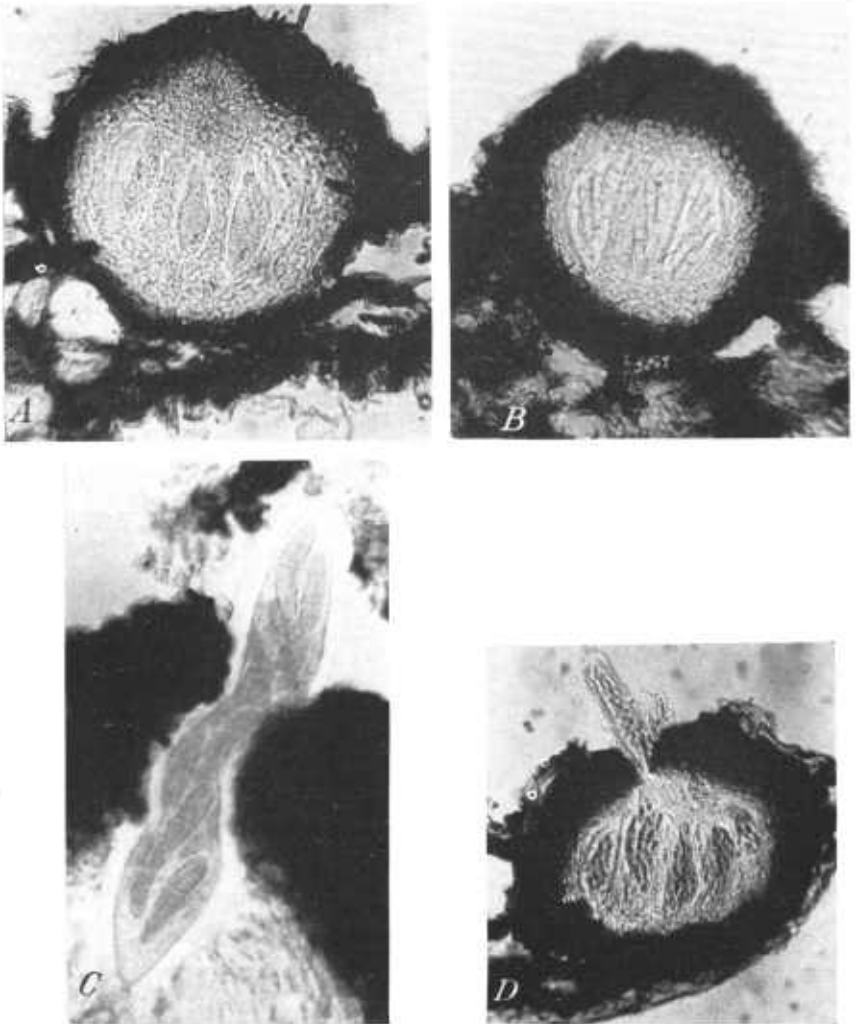
FIGURE 2.—*A*, Immature ascoma of *Rehmiellopsis balsameae*, showing developing asci (× about 320); *B*, immature ascoma of *R. balsameae* with young ascospores (× about 320); *C*, ascus with spores of *R. balsameae* (× about 600); and *D*, ascoma of *R. abietis*, showing asci and spores (× about 275).

and eventually the epidermal cells. Fragments of both kinds of cells are found within the young stroma for some time, but these gradually disintegrate. For the most part, the cells of the young fruiting body

turn a dark brown, leaving only a small central group of hyaline cells containing large oil globules. The hyaline cells develop into a pseudoparenchymatous tissue, which soon involves the greater part of the globoid stroma. A few of the outer cell layers of the stroma develop heavy brown walls, particularly just below the leaf cuticle, which, in August, is split by the rapidly developing fruiting body. The pseudoparenchymatous tissue becomes more loosely woven, and when the fruiting body is crushed on a slide this tissue is extruded as individual globoid, densely granular, hyaline cells that might be mistaken for spores. By late September the outer layers resemble a relatively thick perithecial wall, which merges into an inner layer of subhyaline tissue surrounding the pseudoparenchymatous tissue of the centrum.

In October the young asci become noticeable, developing slowly from a very limited, flat, basal hymenial layer (fig. 2, A). The central asci grow straight up through the stromatic tissue, but the surrounding asci curve outward from the hymenial layer, following the contour of the globoid body. As the thick-walled asci grow upward, the pseudoparenchymatous cells ahead of them break down and disappear, leaving very narrow compressed cells between the asci. In other words, the asci are always surrounded by the pseudoparenchymatous cells (fig. 2, B). When cross sections are cut through the needles, entire asci may drop out, leaving cavities completely surrounded by the stromatic tissue. No paraphyses are present. The fruiting body very frequently develops in the tissue at the edge of the needles and occupies the entire space between the two leaf surfaces. It always opens toward the upper surface, rupturing the cuticle by the formation of a small papillalike protrusion.

There is no further conspicuous development of the asci during the winter, but in early March the outlines of the spores are noticeable and the walls of the asci increase in thickness, particularly at the tips. By the time the spores are mature, the heavy wall-like layers of brown cells at the top of the fruiting body split apart near the center of the papillalike protrusion. No true ostiole is formed. Under favorable conditions of moisture, the pseudoparenchymatous tissue above and surrounding the asci gradually disintegrates and the spores are discharged. Only the dark wall-like layer of cells remains after the spores are extruded, but the cavity soon becomes filled with brown-walled cells forming a sclerotiumlike body. Needles bearing these bodies usually fall off during the following summer.

Asci

The asci are extremely heavy-walled, particularly at the tips (figs. 2, C, and 3, D). The walls measure approximately 5μ to 8μ at the thickest part. The asci are clavate, straight or curved, adhere together in a fascicle, and measure 81μ to 141μ by 33μ to 41μ. They are multispored, containing 16 spores irregularly arranged, and aparaphysate but surrounded by pseudoparenchymatous tissue.

As the ascus matures, a slight internal rupture appears in the heavy wall near the apex and the epiplasmic content expands upward (fig. 4, A). This expansion continues, carrying the spores with it (fig. 4, B), until the top of the ascus is ruptured (fig. 4, C). The epiplasm and spores extrude in the form of a clavate endoascus (fig. 4, D), which eventually withdraws almost completely from the primary sheath

(fig. 4, *E*). The final stage in the liberation of the spores in nature has not been observed, but when mounted in water the entire epiplasmic structure of the mature endoascus collapses, freeing the spores. The latter are usually held together in a gelatinous mass for a short time after expulsion. A similar development of an endoascus has been reported in certain genera of the Sphaeriales, Dothideales, and Myriangiales (*4*), but the character of the ascus wall and the method of spore discharge vary in the different genera. In the fungus here described, the exact nature of the enveloping layer of the expanding endoascus could not be determined; but the layer is extremely thin, though resistant to pressure and moisture until the greater part of the epiplasm and most of the spores have been extruded from the primary
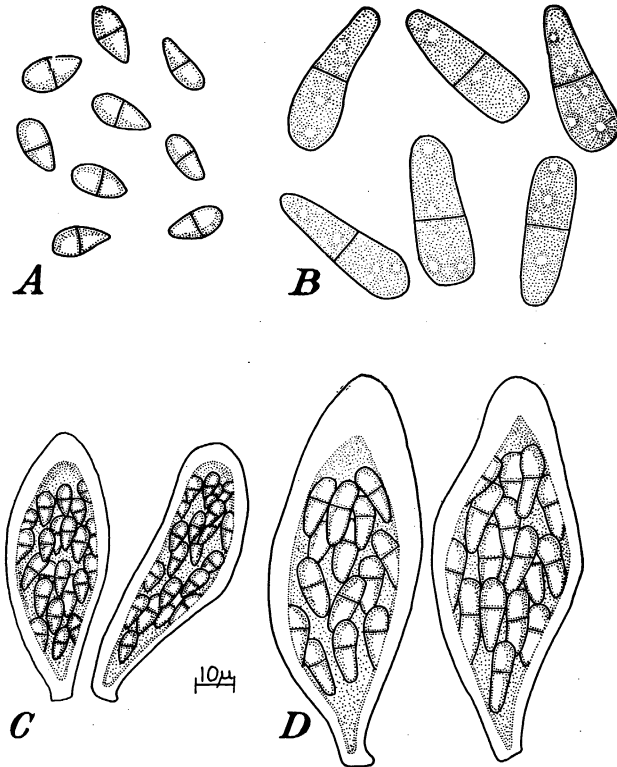
FIGURE 3.—*A*, Mature ascospores of *Rehmiellopsis abietis; B*, mature ascospores of *R. balsameae; C*, immature asci and spores of *R. abietis; D*, immature asci and spores of *R. balsameae*. Drawings made with the aid of a camera lucida.

wall or sheath. This suggests the interpretation given by Stevens and Weedon (*24*), namely, that the epiplasm holds the spores together, thus resembling an ascus.

ASCOSPORES

The ascospores (fig. 3, *B*) are ellipsoidal, two-celled, hyaline, densely granular, heavy-walled, and sometimes slightly constricted at the septum and slightly curved (fig. 2, *C*). The cells are unequal, the one toward the tip of the ascus being shorter, slightly wider, and

rounded at the tip, while the lower cell is more tapering but is also rounded at the end. The spore measurements are as follows: [6] From *Abies concolor* (25 spores), 31.5μ to 47.9μ by 6.3μ to 12.6μ; from *A. balsamea* (25 spores), 37.8μ to 49.9μ by 8.8μ to 12.6μ.

TAXONOMY

In order to determine the identity of the fungus causing the tip blight of species of *Abies* in the United States it was necessary to review the taxonomy of the species of *Rehmiellopsis* causing a similar disease in Europe. In 1905 E. Rostrup (*21*) described *Sphaerella abietis* as the cause of a disease of species of *Abies* in Denmark. He reported the asci as cylindric, 50μ by 10μ, and 8-spored, and the spores as bilocular, colorless, 12μ to 16μ by 5μ to 6μ, with the upper cell the
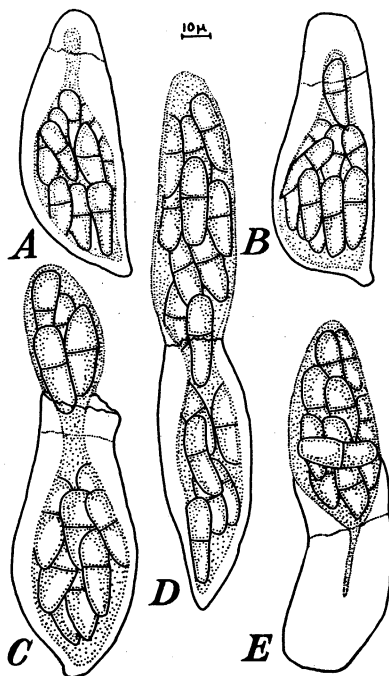
FIGURE 4.—Asci of *Rehmiellopsis balsameae*, showing extrusion of epiplasm and spores from the primary sheath: *A*, Internal rupture of sheath and expanding epiplasm; *B*, spore in expanding epiplasm; *C*, rupture of sheath and extrusion of epiplasm and spores; *D*, epiplasm and spores forming an endoascus; *E*, almost complete withdrawal of endoascus from primary sheath.

larger and with a constriction at the septum. In 1910 Bubák (*2*) also reported a disease of species of *Abies* occurring in Bohemia and caused by an ascomycete with fruiting bodies that opened irregularly and were composed of pseudoparenchymatous tissue. The asci contained 10 to 24 hyaline uniseptate spores. Bubák concluded that, on the

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[6] The spores from these two hosts, as well as those mentioned later from *Abies alba* and *A. lasiocarpa*, were all measured in the same manner. Mature fruiting bodies from herbarium material were crushed on slides in a solution made as follows: Potassium acetate, 10 gm.; pure glycerine, 200 cc.; 95-percent alcohol, 300 cc.; and distilled water, 500 cc. The mounts were allowed to stand in the solution for 24 hours, and 25 spores on each mount were then measured with a filar micrometer. To facilitate the measuring of the spores from *A. alba* and *A. lasiocarpa*, a stain (10 gm. of erythrosin) was added to the solution.

basis of these characters, the fungus did not correspond with any genus previously described; he therefore established the genus *Rehmiellopsis*, designating the species on *Abies* as *R. bohemica* Bub. and Kab. A few years later, O. Rostrup (*22*) found that *S. abietis* E. Rostr. also had more than 8 spores and corresponded in all respects with Bubák's *R. bohemica*. He therefore designated it as *R. abietis* (E. Rostr.) O. Rostr.

In the meantime Lindau (*16, p. 534*) had transferred E. Rostrup's *Sphaerella abietis* to the genus *Mycosphaerella* Johans., and Lind (*15, p. 204*) also published it as *M. abietis* (Rostr.) Lindau, with 8-spored asci. In Saccardo's description of *Mycosphaerella* (*23, v. 9, p. 659*) there is the statement that the genus was established by Johanson in 1884 to include the species formerly placed in the genus *Sphaerella* Fries, since that generic name was preoccupied by the algal genus *Sphaerella* Sommf. However, Saccardo retained the name *Sphaerella* for those species of the fungus genus that had 8-spored asci, and revised Johanson's description of *Mycosphaerella* to include only those species having 16 spores in the ascus. In 1928 he published Bubák's *Rehmiellopsis bohemica* as *M. bohemica* (Bub. and Kab.) Sacc., with *R. abietis* (Rostr.) Rostr. as a synonym (*23, v. 24, p. 893*).

In 1920 Von Höhnel (*11*) questioned the validity of the genus *Rehmiellopsis* and its relation to *Mycosphaerella*. He pointed out that Bubák had placed *M. polyspora* Johans. in the genus *Rehmiellopsis*, since it has more than 8 spores in an ascus, and had also described a new species, *R. conigena*, with 16-spored asci, occurring on cones of *Pinus halepensis* Mill. and *P. pinea* L. (*3*). The latter fungus was found by Von Höhnel (*10*) to be identical with *Sphaeria strobiligena* Desm., which had proved to be a dothideaceous fungus and which he believed to be correctly named *Hariotia strobiligena* by Karsten, as reported by Saccardo (*23, v. 9, p. 672*). Von Höhnel stated also that *R. bohemica* might be a dothideaceous fungus in the same genus.

The question therefore arises as to the proper classification of Rostrup's *Sphaerella abietis*, whether it is a sphaeriaceous fungus in the genus *Mycosphaerella* or a species of the dothideaceous genus *Hariotia*. The type specimen of *S. abietis* Rostr. was not available to the writer, but an examination of Bubák's material on which he based the genus *Rehmiellopsis* showed that the fruiting structure is a simple, globoid, stromatic body with an outer periderm of thick-walled cells resembling a perithecial wall. As Bubák pointed out (*2*), the interior consists of pseudoparenchymatous tissue in which the asci develop, and the fruiting body opens irregularly without the formation of an ostiole. The asci are liberated by the dissolution of the stromal cells directly above them. For the most part these characters correspond with those of the family Pseudosphaeriaceae established by Von Höhnel (*8, 9*) and with the order Pseudosphaeriales, of Theissen and Sydow (*25*). This order includes genera of the Sphaeriales and particularly of the Mycosphaerellaceae, in which the fructifications have no true perithecial wall and ostiole and are composed of pseudoparenchymatous tissue surrounding the developing asci. Petrak (*20, p. 67*), in a discussion of the Pseudosphaeriaceae, interpreted the strands of tissue between the asci as primitive paraphyses, resulting from the pressure of the developing asci, and called them paraphysoids. In Bubák's specimen, no paraphysoids of this

type are present but the asci are separated by narrow cells of the pseudoparenchymatous tissue. In a crushed mount of a mature fruiting body this tissue is extruded as individual cells and not as strands.

Miller (*17*) has indicated that the pseudosphaeriaceous type of ascocarp is similar to that of the Dothideales, in which the asci are surrounded with stromal tissue. He pointed out that the paraphysoids of the Pseudosphaeriales develop as definite threads from ascogenous hyphae and are not the result of compression of the tissue by the developing asci (*18*). He considered this one of the points of distinction between the Dothideales and the Pseudosphaeriales, the genera *Dothidea* and *Mycosphaerella*, which have no paraphyses or paraphysoids, being representative of the former order. However, most species of *Mycosphaerella* have been described as having ostiolate perithecia and are commonly classified in the Sphaeriales, although a few have been reported as dothideaceous (*6, 19*). Since Bubák's *Rehmiellopsis bohemica* and the species described in the present study are of the dothideaceous type, it seems inadvisable to consider them species of *Mycosphaerella* until further investigations of that genus have been made.

As already mentioned, Von Höhnel (*11*) considered it possible that Bubák's *Rehmiellopsis bohemica* might prove to be a dothideaceous fungus in the genus *Hariotia* Karsten. An examination of Desmazières' *Sphaeria strobiligena*, upon which Karsten based the genus *Hariotia* and which Von Höhnel stated was identical with *R. conigena* Bub., shows that the fruiting body is not at all the same as in *R. bohemica*. In the former the stroma is pulvinate rather than globoid, with a hypostroma, and is conspicuously erumpent, with the periderm differentiated but not resembling a perithecial wall; the asci are numerous and do not adhere in a fascicle. Therefore *R. bohemica* cannot be considered a species of *Hariotia*, nor does it correspond exactly with any other genus of the Dothideales.

Since Bubák's *Rehmiellopsis bohemica* does not correspond with *Mycosphaerella* in the Sphaeriales or with *Hariotia* in the Dothideales, it is at present difficult to assign the genus *Rehmiellopsis* Bubák to any definite place in the systematic key. A cytological study of *Rehmiellopsis* in comparison with similar dothideaceous genera and also with the species of *Mycosphaerella* having dothideaceous characters might reveal the relation of *Rehmiellopsis* to those genera. Under the circumstances, the writer has chosen to retain the generic name *Rehmiellopsis*, with Bubák's *R. bohemica* as a synonym of *R. abietis* (E. Rostr.) O. Rostr., and to assign the genus to the Dothideales.

A detailed study of specimens of *Rehmiellopsis abietis* from various sources indicated the important points of distinction between this species and the one occurring in the eastern part of the United States. Included in the study were the following specimens.

On *Abies alba*: Wartenberg, Bohemia, collected by J. E. Kabat, determined by F. Bubák, April 1909, type specimen, on file in herbarium of the Brooklyn Botanical Garden, Brooklyn, N. Y.; S. Hareskov, Denmark, coll. and det., O. Rostrup, Oct. 1925, not type material, submitted to the writer by G. D. Darker; Almindingen, Bornholm, Denmark, coll. and det., J. S. Boyce, Sept. 1925, No. 1546, herbarium of J. S. B.; Loch Awe, Argyllshire, Scotland, coll., J. S. Boyce, det., M. Wilson, Aug. 1925, Nos. 1547 and 1548, herbarium of J. S. B.

On *A. nobilis:* Corrour, Inverness-shire, Scotland, coll. and det., J. S. Boyce, Aug. 1925, No. 1549, herbarium of J. S. B. On *A. lasiocarpa:* Edgewood, British Columbia, coll., L. N. Goodding and J. W. Kimmey, June 1932 and Sept. 1935, det., A. M. Waterman, Forest Pathology collections 93326 and 93327.

The characteristics of the hyphae and the development of the ascomata are the same in both species. However, the mature ascomata of *Rehmiellopsis abietis* (fig. 2, *D*) are slightly smaller, containing a greater number of smaller asci with narrower walls and smaller spores. The asci measure 50μ to 90μ by 20μ to 22μ, with walls 3μ to 5μ at the thickest part, and contain 16 to 24 spores irregularly arranged (fig. 3, *C*). The spores (fig. 3, *A*) are 2-celled, hyaline, finely granular, with thin walls, not constricted at the septum, straight, with the 2 cells of about equal length, the upper cell very slightly the broader and the lower definitely acute at the tip. The spore measurements are as follows: From *Abies alba* (25 spores), 11.1μ to 21μ by 4μ to 6.3μ; from *A. lasiocarpa* (25 spores), 12.6μ to 18.5μ by 4.2μ to 6.7μ.

Bubák (*2*) reported a pycnidial fungus, in association with the perfect stage of *Rehmiellopsis abietis*, on *Abies alba* in Bohemia, and named it *Phoma bohemica*. He stated (*p. 318*) that "Es ist vollkommen sicher, dass beide Pilze genetisch verbunden sind," but gave no proof. The similarity in the early development and superficial appearance of the two types of fruiting bodies and the fact that the pycnidial form apparently was always associated with the perfect stage seemed to be the basis for the statement. E. Rostrup (*21*) reported a similar pycnidial fungus on infected *Abies* in Denmark, and O. Rostrup (*22*) also mentioned it on *A. alba*. Jørstad (*13*) was not certain that he found this imperfect stage in Norwegian material, but Wilson and MacDonald (*28*) reported it on species of *Abies* in Scotland. In the writer's examination of the herbarium specimens previously mentioned, this imperfect stage was found only on Bubák's specimens of *A. alba* and on those of *A. lasiocarpa* from British Columbia. The writer has not made a cultural study of this pycnidial fungus from fresh material to prove its relationship to *R. abietis*.

Bubák's (*2, p. 320*) description of these pycnidia reads as follows: "contextu crasso, nigrofusco, pseudoparenchymatico, intus paulatim hyalino, papilla conica erumpentibus, hicque irregulariter dehiscentibus." This suggests a method of development resembling that of the perfect stage, which is indeed the case. Bubák, however, reported the presence of conidiophores: "basidiis cylindricis, brevibus, ad apicem attenuatis, hyalinis vel parum luteolis"; but in fact the spores are produced directly from the cells of the hymenial layer, which are slightly modified in shape, suggesting "ad apicem attenuatis." While the spores are forming, the pseudoparenchymatous tissue of the interior of the fruiting body undergoes disintegration and the short papilla is ruptured without the formation of an ostiole. It is evident that the fungus is not a true *Phoma* or *Macrophoma*, but according to the classification of imperfect fungi given by Clements and Shear (*5, p. 178*), it might be considered a species of *Dothichiza*. The spores in the *Abies lasiocarpa* material corresponded in all respects with those found in Bubák's specimens. No imperfect fungus of this type has been found in the many collections of the species of *Rehmiellopsis* on *A. balsamea* and *A. concolor* examined by the writer.

The species of *Rehmiellopsis* on *Abies balsamea* and *A. concolor* in the eastern part of the United States is designated as *R. balsameae* n. sp., on the basis of the size of asci and spores and the smaller number of spores per ascus. For the sake of comparison the two species of *Rehmiellopsis* on species of fir are here described.

Rehmiellopsis abietis (E. Rostr.) O. Rostr. (emended description).

     Syn.: *Sphaerella abietis* E. Rostr., 1905, Tidsskr. Skov. 17: 39.

        Mycosphaerella abietis (E. Rostr.) Lind., 1908, *in* Sorauer: Handb. Pflanzenkr. Aufl. 3, Bd. 2: 534.

        Rehmiellopsis bohemica Bub. and Kab., 1910, Naturw. Ztschr. f. Forst. u. Landw. 8: 320.

        Mycosphaerella bohemica (Bub. and Kab.) Sacc., 1928, Syll. Fung. 24: 893.

Ascomata amphigenous, usually epiphyllous, subepidermal becoming erumpent, single or rarely aggregate, globose, pseudoparenchymatous with differentiated periderm on all sides, opaque at the top, papillalike, rupturing irregularly, 150μ to 200μ in diameter. Asci clavate to cylindric, short stipitate, thick-walled, thickened at the apex, 3μ to 5μ at thickest point, straight or slightly curved, adhering together in a fascicle, 50μ to 90μ by 20μ to 22μ, many-spored (16 to 24), no paraphyses. Ascospores ellipsoid, irregularly arranged, hyaline, 11.1μ to 21μ by 4μ to 6.7μ, uniseptate, not constricted at septum, finely granular, straight, cells about equal in length, upper cell slightly broader and rounded at tip, lower cell tapering with acute point.

Pycnidia subepidermal becoming erumpent, single, globose with slight papilla, opening irregularly, pseudoparenchymatous, 150μ to 200μ in diameter. Spores oblong or fusiform, straight or slightly curved, slightly pointed at both ends, hyaline, continuous, 10μ to 16μ by 4μ to 6.5μ, produced directly from the cells of the hymenial layer.

Habitat.—In Europe: On living leaves of *Abies alba* in Denmark, Norway, Bohemia, and Scotland; of *A. pinsapo* Boiss. in Denmark, Norway, and Scotland; of *A. nobilis* and *A. cephalonica* in Denmark and Scotland; of *A. nordmanniana* (Steven) Spach in Denmark; of *A. sibirica* Ledeb. in Norway; and of *A. pindrow* Royle in Scotland. In North America: On living leaves of *A. lasiocarpa* in British Columbia, Canada.

Rehmiellopsis balsameae n. sp.

Ascomata amphigenous, usually epiphyllous, subepidermal becoming erumpent, single or rarely aggregate, globose, black, pseudoparenchymatous with differentiated periderm on all sides, opaque at the top, papillalike, rupturing irregularly, 200μ to 250μ in diameter. Asci clavate to cylindric, short stipitate, thick-walled, conspicuously thickened at the apex, 5μ to 8μ at thickest point, straight or curved, adhering in a fascicle, 81μ to 141μ by 33μ to 41μ, 16-spored, no paraphyses. Ascospores fusiform-elliptic, irregularly arranged, hyaline, 31.5μ to 49.9μ by 6.3μ to 12.6μ, 1–septate, sometimes slightly constricted at septum, densely granular, straight or curved, cells unequal, upper cell shorter and slightly broader, lower cell longer and tapering but rounded at end.

Conidial stage not observed.

Ascomatibus amphigenis sed plerumque epiphyllis, subepidermicis, innato- • erumpentibus, sparsis vel rare aggregatis, globosis, nigris, contextu pseudoparenchymatico, astomis, 200μ–250μ in diam.; ascis cylindraceo-clavatis, breve stipitatis, membrana crassa, 5μ–8μ ad apicem, rectis vel curvatis, 81μ–141μ× 33μ–41μ, 16-sporis, aparaphysatis; sporidiis fusiformi-ellipticis, inordinatis, hyalinis, 31.5μ–49.9μ×6.3μ–12.6μ, 1–septatis, interdum leniter constrictis, rectis vel curvatis, cellulis plerumque inaequalibus, utrinque obtusis.

Fructificationibus conidicis non visis.

Habitat.—On living leaves of *Abies concolor, A. balsamea, A. cephalonica, A. nobilis,* and *A. fraseri.* Type specimen, 93300,[7] on leaves of *A. concolor,* Hamilton, Mass., collected by M. A. McKenzie and K. F. Aldrich, May 4, 1934, has been deposited in the Mycological Collections, Plant Industry Station, Beltsville, Md. Cotype specimens are filed in the herbaria of the New York Botanical Garden and the Brooklyn Botanic Garden and in the Farlow Herbarium, Harvard University, Cambridge, Mass. Additional specimens of the fungus on species of *Abies,* included in the study, are on file in the Forest Pathology Laboratory, Bureau of Plant Industry, Soils, and Agricultural Engineering, at New Haven, Conn., as follows:

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[7] Collection numbers are those of the Division of Forest Pathology.

On Abies concolor.—Massachusetts: 93301, Hamilton, coll. A. M. Waterman and K. F. Aldrich;[8] 93302, Hamilton, coll. K. F. A. Maine: 93303, Augusta, coll. K. F. A. and M. A. McKenzie; 93304, Augusta, coll. K. F. A.; 93305, Cape Elizabeth, coll. R. W. Nash; 93312, Flagstaff, coll. K. F. A. New Hampshire: 93308, Rye Beach, coll. Mrs. James Morrison. New York: 93306, Lake George, coll. K. F. A. and McK.; 93307, Lake George.

On Abies balsamea.—Maine: 88963, Eustis, coll. J. R. Hansbrough; 94184, Flagstaff; 93313, South China, coll. C. K. Goodling; 93314, Ripogenus Dam; 93315, Oquossoc; 93316, Jim Pond Township; 93317, Kokadjo; 93318, Pittston Farm; 93319, Sandwich Township. New Hampshire: 93320, Stewartstown; 93321, Colebrook; 93322, Errol; 93323, Second Connecticut Lake; 93324, Pittsburg. Vermont: 93325, Lemington.

On Abies cephalonica.—Rhode Island: 93309, Bristol.

On Abies nobilis.—Massachusetts: 93310, Hamilton.

On Abies fraseri.—Massachusetts: 93311, Hamilton.

CULTURAL CHARACTERISTICS

Cultures of *Rehmiellopsis balsameae* from single ascospores, asci, and newly infected leaf tissue were made on corn-meal, oatmeal, and potato agars, corn mush, potato plugs, and Leonian's (*14*) synthetic agar. The last-named gave the most uniform results. The ascospores germinated readily in water, even while still in the ascus, but hyphal growth on all the media was extremely slow. In about 48 hours the very short, brownish hyphae produced, on Leonian's agar, small, ovoid, hyaline spores, budding directly from the hyphal cells. This process continued for a few days only, giving a brownish-black yeast-like appearance to the agar. In the meantime a very limited amount of a reddish-brown aerial mycelium began to appear. This continued until a maximum growth of about 10 to 12 mm. in diameter was reached, after which there was no further development. On the other media growth was even more limited, consisting only of a slight yeastlike growth followed by an exceedingly scanty aerial growth.

Transfers were made from single-ascospore cultures on Leonian's medium to sterilized potato plugs and to sterilized needles of *Abies concolor*. On the former, only a yeastlike growth, with a very little aerial mycelium, developed. On the sterilized needles, immature fruiting bodies characteristic of *Rehmiellopsis* were formed in about 2 weeks. These fruiting bodies did not produce spores of any kind, but their method of development was identical with that found in nature. The mycelium produced in cultures on Leonian's medium and in the sterilized needles was comparable in color and width of hyphae with that found in the leaf tissues in nature when fruiting bodies are producing spores. Cultures, both on agar and on sterilized needles, were grown in the greenhouse to determine whether conditions of light and heat different from those in the laboratory might influence the development of mycelium and fruiting bodies. No change of any kind, however, was evident. Single-ascospore cultures from *A. balsamea*, grown on Leonian's medium, were identical with those of the fungus isolated from *A. concolor*.

PATHOGENICITY

PATHOLOGICAL ANATOMY

In the needles of both *Abies balsamea* and *A. concolor* the hyphae of *Rehmiellopsis balsameae* are usually evident first in the intercellular spaces below the stomata. The cells of the mesophyll in the vicinity

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[8] Unless otherwise indicated, collections were made by A. M. Waterman and K. F. Aldrich.

soon turn brown, and the hyphae branch out between them. The browning of the cells very conspicuously precedes the advance of the mycelium, suggesting the possibility of a toxic effect by the fungus. A similar condition was reported by Wilson and MacDonald (*28*) in their examination of the effect of *R. abietis* on *A. alba* in Scotland. As the browning continues, the leaf cells become shrunken and gradually filled with mycelium until all the tissue, except the vascular cells, is affected. The vascular tissue shows no invasion by the hyphae until the complete destruction of all other leaf tissue. The spread of the mycelium in the leaf tissue is relatively slow, and the massing of the hyphae for the formation of fruiting bodies is usually evident before the destruction of all the cells in the area.

In some cases on *Abies concolor*, the mycelium from the leaf penetrates into the twig, causing a small canker around the base of the leaf. This seems to occur if infection takes place before the leaf reaches maturity or if the locus of infection is at or near the base of the leaf. The mycelium spreads into the twig first at the periphery of the absciss layer, and in some cases it does not penetrate farther. If the vascular tissue is affected, however, the browning of the twig cells occurs slowly and is followed by the spread of the hyphae, resulting in the formation of a canker. Cankers are formed on the terminal twigs more frequently than on laterals, but both terminal and lateral twigs may be killed back partly or entirely to the nodes. This dieback occurs when infection takes place in the majority of the needles of a twig before they reach maturity, and every needle is eventually affected. All the cells of the twig become brown and shrunken and even the cells of the absciss layer are invaded by the fungus. The death of the twigs, therefore, seems to be the result of the accumulated effects of the fungus in all the needles, whereas the formation of a canker depends on the spread of the mycelium from one infected needle. The partial dieback of a twig is followed by the development of adventitious buds below the lesion, but the growth developing from such buds is usually weak and stunted. No cankers have been found on *A. balsamea*, but both terminal and lateral twigs frequently die back to the node.

The effect of the disease on the tree as a whole depends upon the number of buds that escape infection and are able to produce a normal healthy growth the following season. When twigs are killed back to the node, further growth of that particular section of the branch is possible only from the adventitious buds. Since it is usually the laterals that are killed back, the continuance of growth from the normal terminal buds helps to counteract the effect of the dieback and is responsible for deferring the death of a diseased tree.

ARTIFICIAL INOCULATIONS

MATERIALS AND METHODS

Four series of inoculations were made in the greenhouse on 5-year-old potted trees of the following species of fir: *Abies concolor*, *A. fraseri*, *A. lasiocarpa* var. *arizonica* (Merriam) Lemm., *A. veitchii* Lindl., *A. homolepis* Sieb. and Zucc., and *A. holophylla* Maxim. In three of these series, the inoculum consisted of small amounts of mycelium and agar from single-ascospore cultures of *Rehmiellopsis balsameae*, isolated from *A. concolor* and grown on Leonian's (*14*) medium, and also aerial

mycelium from transfers of these cultures to sterilized needles of *A. concolor*. The mycelium was placed on buds or newly developed needles, and in two of the series the inoculated parts were wrapped in moist cotton and covered with a celluloid cylinder plugged at both ends with moist cotton. On the inoculated trees of the third series, this type of wrapping was not used but the trees were covered with bell jars shaded from the sun. In all cases, the coverings were removed in a week or 10 days and the trees were shaded from direct sunlight by cheesecloth. In the fourth series in the greenhouse, the inoculum consisted of a water suspension of crushed needles bearing fruiting bodies with mature asci and spores of *R. balsameae*, freshly collected from infected trees of *A. concolor*. By means of a pipette a few drops of the suspension were placed on the newly developing needles, and the whole shoot was then wrapped in moist cotton and a celluloid cylinder. The coverings were removed after the same interval as in the other series.

A nursery plot of 5- to 8-year-old trees of *Abies concolor, A. balsamea, A. fraseri, A. lasiocarpa* var. *arizonica, A. veitchii, A. nobilis, A. homolepis*, and *A. holophylla* was established for inoculations in a situation in Rhode Island that proved to be exceptionally favorable for the growth of most of the trees. *A. balsamea, A. lasiocarpa* var. *arizonica*, and *A. nobilis* were in general less vigorous but produced new growth sufficient for inoculations. A total of 189 inoculations were made in the following years: In 1935, 9 in May, 20 in July; in 1936, 14 in June; in 1938, 26 in June, 54 in July; in 1940, 66 in May. In the May 1935 series, 3 inoculations on 3 trees of *A. concolor* were made, the inoculum consisting of small pieces of mycelium and agar from single ascospore cultures of *Rehmiellopsis balsameae* isolated from *A. concolor*. The inoculum was placed on the upper surface of the newly developed needles of a terminal twig, and this twig and the two adjacent laterals were wrapped together in moist cotton and covered with a strip of waxed paper tied firmly at both ends. It was necessary to include the laterals, since the weight of the wrappings could not be supported by the tender terminal twig alone. In all the other series the inoculum consisted of infected needles of *A. concolor* or *A. balsamea* bearing mature fruiting bodies and spores of *R. balsameae* which had been slightly crushed in water to partly liberate the asci and spores. With sterilized forceps 3 or 4 of these crushed needles were placed on the upper surface of the newly developed needles of a terminal twig and wrapped as already described. In all cases the coverings were removed after an interval of 10 days or 2 weeks. Usually 2 or more inoculations were made on 1 tree, on widely separated shoots.

In the spring of 1941 an attempt was made to devise some method that would be more nearly comparable to the conditions under which infection takes place in nature and would eliminate the cotton and waxed-paper wrappings. "Iceless refrigerators" of the type described by Hunt (*12*) were built with a framework 2 feet wide by 2 feet deep by 4 feet high and were placed over two trees each of *Abies concolor* and *A. balsamea*. Twigs of these same species of *Abies*, bearing infected needles with mature fruiting bodies and spores of *Rehmiellopsis balsameae*, were kept moist for about 12 hours after collection and then fastened firmly on the young shoots of the current season's growth by means of fine copper wire wrapped around the

twigs of the previous year's growth. Five cross inoculations were made on each tree, and the infected needles were carefully intermingled with the needles of the young shoots. Pans 6 inches deep were then set on the framework and filled with water. The whole framework was covered with two thicknesses of unbleached cotton cloth, which was constantly moistened with the water from the pans. During bright sunlight in the middle of the day the cloth was kept thoroughly soaked with additional water from a garden hose. The iceless refrigerators were removed after 48 hours, but the twigs and needles used as inoculum were left wired to the trees for 2 weeks.

EXPERIMENTAL RESULTS

Two of the series of inoculations in the greenhouse were made in late February and early March, before the buds had opened, to determine whether bud infection was responsible for the earliest symptoms of the disease in nature. No infection occurred in any case, and the fungus seemed to be unable to penetrate the bud scales or to infect the twig tissue at the base of the buds. Later in the season, when the new needles were emerging from the buds, the other series were made, but no infection resulted. It was thought that the greenhouse conditions, particularly temperature, were unfavorable for the fungus.

In the first series of inoculations in the nursery plot in May 1935, 3 inoculations on 3 trees of *Abies concolor*, made with mycelium of *Rehmiellopsis balsameae* from culture as inoculum, resulted in infection on 2 of the trees. The following October a few of the needles showed fruiting bodies, and upon examination these were found to contain developing asci characteristic of *R. balsameae*. The fungus was not reisolated at this time, since the remaining infected needles were left on the trees to overwinter to determine whether mature spores would be produced in the spring. However, none of the infected needles could be found in the spring of 1936, having broken off during the winter. Of the 26 inoculations made in 1935 with crushed infected needles of *A. concolor* as inoculum, 7 were made on *A. concolor*, 6 on *A. fraseri*, 6 on *A. holophylla*, 3 on *A. lasiocarpa* var. *arizonica*, 2 on *A. homolepis*, and 2 on *A. veitchii*. No positive results were obtained.

In 1936 the type of inoculum just described was used in the 14 inoculations, as follows: 4 on *Abies concolor*, 6 on *A. fraseri*, 1 on *A. holophylla*, 2 on *A. homolepis*, and 1 on *A. veitchii*. In October immature fruiting bodies were found in all 4 of the inoculations on *A. concolor* and in 2 of those on *A. fraseri*. No material was collected for reisolating the fungus, but all infected needles were left to overwinter on the trees. The following spring 1 inoculation on each of these 2 species of *Abies* had resulted in the formation of mature fruiting bodies and spores of *Rehmiellopsis balsameae*. Because of the limited amount of infected material, no attempt was made to reisolate the fungus. All other needles that had produced fruiting bodies in the autumn had fallen off during the winter. No infection occurred on the 3 other species of *Abies*.

In 1938 and 1940 further attempts were made to obtain infection by cross inoculations with the same type of inoculum as was used in 1936 and to carry infection through to the following spring, thus obtaining

mature spores and, if possible, natural infection of the new growth. Table 1 shows the number of inoculations made in the 2 years. The phrase "possible infections" in the table indicates the presence of characteristic symptoms of infection and what appeared to be fruiting bodies of *Rehmiellopsis balsameae* as seen under a hand lens when examined in the autumn. None of the diseased needles were removed at that time and no reisolation of the fungus was attempted, because of the very limited number of needles showing infection and the lack of sufficiently distinctive cultural characteristics for an exact identification. During the winter and early spring in both years, however, all apparently infected needles were broken off by winds or storms and no evidence of the fungus could be found. Therefore the results of these inoculations are entirely inconclusive.

It was also found that several days of rain during the period when the inoculated shoots were covered with cotton and waxed-paper wrappings would cause a serious mold of both needles and twigs, even in the controls. In some cases the entire shoots would break off when the wrappings were removed, and it was evident that all shoots were appreciably weakened by the process. For this reason it was thought that the iceless refrigerators would prove more efficient. However, in the 20 cross inoculations made under these conditions no positive results were obtained. On 3 of the inoculated shoots of *Abies balsamea* a few apparently infected needles were found the following autumn, but by the next spring these needles had broken off.

In the inoculations made by artificial methods, therefore, positive results were obtained from three inoculations on *Abies concolor* and one on *A. fraseri*.

TABLE 1.—*Record of inoculations made on species of Abies with Rehmiellopsis balsameae*

| | Source of inoculum | | | |
| Year and species of *Abies* inoculated | *Abies concolor* | | *Abies balsamea* | |
	Inocula-tions	Possible infections [1]	Inocula-tions	Possible infections [1]
1938	*Number*	*Number*	*Number*	*Number*
A. concolor	6	1	6	6
A. balsamea	12	0	12	8
A. fraseri	12	0	12	6
A. veitchii	2	0	4	1
A. nobilis	3	0	4	4
A. holophylla	3	0	4	1
Total	38	1	42	26
1940				
A. concolor	20	17		
A. balsamea	20	2		
A. fraseri	18	4		
A. veitchii	8	2		
Total	66	25		

[1] Characteristic symptoms and fruiting bodies, but no mature asci or spores. The needles broke off during the winter; therefore, the fungus did not reach maturity.

NATURAL INFECTION

In view of the difficulties encountered in obtaining positive results from cross inoculations by artificial methods, it was thought advisable

to test the susceptibility of various species of fir under natural conditions of infection. The results obtained from this experiment with seven species of *Abies* have already been reported (*26*), proving the susceptibility of *A. fraseri* and *A. nobilis* to *Rehmiellopsis balsameae*. *A. holophylla* was reported as apparently resistant, but on one of the trees of this species a few discolored needles were found in the fall of 1937. The next spring an examination of these needles showed mature fruiting bodies and spores of *R. balsameae*. It is evident that this species is only slightly susceptible and that the disease probably never would be of any significance on this host.

Mention has been made of the fact that surveys of infection areas in New England and New York have shown no indication of any connection between infection on native *Abies balsamea* and on introduced *A. concolor*. In order to test the possibility of cross infection of these hosts in nature, two small 6-year-old nursery trees of *A. concolor* were planted early in the spring of 1940 under the infected branches of two widely separated trees of *A. balsamea* growing in native stands in Flagstaff, Maine. Neither of the white firs showed evidence of infection that season, possibly because the season was unfavorable for infection even on native trees. Since the disease seemed to have subsided entirely on one of the balsam firs, the white fir in that vicinity was removed in the autumn. On the other white fir, symptoms of infection appeared in 1941, and in 1942 considerable infection was present on the newly developing growth (fig. 1, *C*), with mature fruiting bodies and spores of *Rehmiellopsis balsameae* on the 1941 needles. This, together with the previously reported results (*26*), gives definite proof that *R. balsameae* will cross-infect at least four species of fir: From *A. balsamea* to *A. concolor;* and from *A. concolor* to *A. fraseri*, *A. nobilis*, and *A. holophylla*. In this connection it is interesting to note that Boyce (*1*), in his observations of the disease of firs caused by *R. abietis* in Europe, pointed out that *A. nobilis* was the only American species of fir susceptible to that disease.

CONTROL

Since the tip blight on native balsam fir already is distributed over a large area of northern Maine, control measures for these forest trees would be impossible. The severity of the disease varies considerably from one season to another, and the affected trees show a striking ability to counteract the injury from infection, although some weakening always results after a fairly severe attack. For this reason, the tip blight has not yet caused any appreciable damage to older trees, but its particular menace in this region is to the young seedling trees. It is not known how long the disease has been prevalent on the native trees in Maine, but probably at least since 1930. Apparently tip blight has been moderately abundant across the border in Canada since 1919 (*7*). Its significance as a forest-tree disease in the United States is not yet definitely known.

Tip blight on white firs in the East is important because these trees are widely used as ornamentals and are highly valued for that purpose. Ornamental plantings of this species have been found as far north in Maine as Farmington, in the western part of the State, and Millinocket, in the eastern part. It is evident, from the results of the experiments with natural infection, that the planting of this species in the vicinity of infected balsam firs should be avoided.

Two series of spray experiments were undertaken to determine the possibility of controlling the disease on ornamentals by this means. In the infected planting of *Abies concolor* in eastern Massachusetts, 2 plots were selected in which the trees showed various degrees of infection. In 1 plot of 19 trees about 6 to 20 feet in height, 1 tree was heavily infected, 4 were slightly infected, and the remainder had only a few needles with fruiting bodies. A total of 26 other trees in the vicinity, lightly infected or free from disease, were left as checks. The second plot of 22 trees, which were of approximately the same height as those in the first plot and about half of which were heavily infected, was selected in the large planting where the disease was first found.

About the middle of May 1936, the first application of spray was made in both plots. The buds were then just opening, and the green of the new leaves was beginning to show. A 2–2–50 bordeaux mixture, with casein as a spreader, was applied thoroughly. A good coverage of the new growth was obtained, and no burning of the young needles resulted. A week later a severe frost injured the new growth of some of the trees in both plots. Only those needles at a certain stage of development, that is, just showing green in the bud, were affected, and the growth that had developed sufficiently to receive the application of spray was largely uninjured. A slight amount of infection, however, was becoming noticeable when the second application of spray was made, about 10 days after the first. The strength of the spray in this application was increased to 4–4–50. Some evidence of control was noticeable on the sprayed trees in comparison with the unsprayed, but no further application was made that season. A moderate amount of infection occurred on the sprayed trees after the second application, and on the unsprayed trees the infection was relatively heavy.

In 1937 the experiment was repeated in both plots, the 4–4–50 bordeaux mixture with casein being used for the first application. The spray was applied about a week later than in the preceding year, owing to a slightly later seasonal development of growth. Twelve days after the first application a second application of the same strength was made in the two plots, at which time no appreciable amount of infection was noticeable, even on unsprayed trees. In a week, however, a fairly severe attack of the disease occurred, and the contrast between sprayed and unsprayed trees was striking. The former showed only scattered needle infections, whereas on the latter much of the new growth was killed back to the nodes and needle infection was abundant. A third application of the spray was made 12 days after the second to protect the late-developing growth. The sprayed trees came through the season in fine condition and gave excellent evidence of the value of the treatment, even in areas of severe infection. No burning of the new growth resulted in any case, and good coverage as well as effective adhesiveness was obtained. There was no frost injury during the experiment.

From these experiments it was evident that the time element, particularly for the first application of spray, is of special importance in securing satisfactory results. The first application should be made as soon as the buds begin to show green and should be followed by two additional applications at intervals of about 10 or 12 days. The period during which infection takes place is comparatively short,

depending upon the stage of development of the new growth, the maturity of the fungus spores, and weather favorable for the germination of the spores. The height of severity of infection may fall within the period between the first two applications or between the last two, but the three applications should provide satisfactory control.

Bubák (*2*) and Wilson and MacDonald (*28*) advocated cutting off and burning branches of ornamentals affected by *Rehmiellopsis abietis* as soon as the disease appears, but this practice seems unnecessary for the control of *R. balsameae*. In fact, it might even retard the recovery of affected trees, since it is difficult to determine superficially what buds are affected, and healthy buds that would develop normal growth might be inadvertently removed. If the disease progresses on a tree for several seasons to the point where the lower branches are materially weakened or killed, these branches should be removed and burned for the sake of the general appearance of the tree. A carefully followed spray schedule, however, should prevent the killing back of the branches to any appreciable extent.

SUMMARY

A tip blight of native trees of *Abies balsamea* in northern New England and of ornamental trees of *A. cephalonica* in southern New England and *A. concolor* in New England and New York is caused by *Rehmiellopsis balsameae*, a new species. The disease in many respects resembles that caused by *R. abietis* in Europe on *A. alba, A. nobilis, A. pinsapo, A. nordmanniana, A. pindrow, A. cephalonica,* and *A. sibirica,* and in British Columbia on *A. lasiocarpa.*

The needles of the current season's growth are attacked by the disease, and a dieback of terminal or lateral shoots may result. Cankers are sometimes formed on twigs of *Abies concolor* at the base of infected needles.

Infection takes place early in the spring just as the new growth is developing. The fruiting bodies of *Rehmiellopsis balsameae* begin to form soon after infection, but the spores do not mature until the following spring. No imperfect stage of *R. balsameae* has been observed.

Inoculation experiments proved the pathogenicity of *Rehmiellopsis balsameae* on *Abies concolor* and also showed that *A. fraseri* is susceptible. Small nursery trees of *A. fraseri, A. nobilis,* and *A. holophylla,* planted in an area of infected trees of *A. concolor,* proved susceptible to natural infection. Cross infection from *A. balsamea* to *A. concolor* was obtained by planting a young tree of the latter species under a heavily infected native balsam fir.

The importance of the tip blight as a disease of forest trees is not yet definitely known, but because of its wide distribution on native balsam firs control measures would not be feasible in the forest. On ornamental white firs satisfactory control was obtained by three applications of spray at intervals of 12 days, of a 4–4–50 bordeaux mixture to which casein was added as a spreader. The first application of the spray should be made as soon as the new growth begins to emerge from the buds.

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