CHRYSOMYXA EMPETRI — A SPRUCE-INFECTING RUST

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With one text figure and plates 202, 203

Chrysomyxa Empetri (Persoon) Schroeter has been known for considerably more than a century, but only on *Empetrum* and almost solely with respect to its uredo-stage. DeCandolle (5) described its uredia in 1815 from specimens distributed two years earlier in Mougeot and Nestler's Stirpes Cryptogamae Vogeso-Rhenanae and to which Persoon had attached the name *Uredo Empetri.* Link (10), Wallroth (14) and Karsten (8) in turn, and in each instance on wholly untenable grounds, transferred it to the genera *Caeoma, Erysibe* and *Thecopsora,* respectively. Schroeter (12), basing judgment on the uredia, just as did the others but with happier discrimination, placed it in the genus *Chrysomyxa.* The following year (1888) and apparently independently, Rostrup (11) also referred it to *Chrysomyxa;* but he did so with a probably better reason because he stated he had found the telia on *Empetrum nigrum* in Greenland. Rostrup did not describe the telia and what became of the collections he may have made is not known. That both Schroeter and Rostrup were right, however, was recently substantiated by Jørstad (7) who described the telia in 1935 from specimens long preserved in the Botanisk Museum, Oslo — specimens which had been collected by Axel Blytt, July 1887, at Sør-Trøndelag, Kongsvoll in Opdal, Norway. Through the courtesy of Professor Jørstad I have had the opportunity of examining this material. Unquestionably the rust is a *Chrysomyxa.*

Collections of *Chrysomyxa Empetri* on *Empetrum nigrum* have been made in most of the major areas of distribution of *E. nigrum* (6) and recently Arvidsson (3, 4) has reported it on a collection of *E. rubrum* in the Gray Herbarium of Harvard University — a collection made some years ago by W. S. Brooks in the Falkland Islands. Indeed, it occurs so frequently in both mycological and phanerogamic herbaria that it can properly be classed as a very common, widely-distributed rust. Except, however, as noted above, the uredo-stage only has been recognized. Scant as have been the findings of the telial stage, for the haploid phase there have been no claims at all. If collections have been made, they have been referred to other species. Of course it is generally assumed that there is or has been a haploid phase and that it probably would be on an alternate host. But the assumption has rested wholly on analogy, because there has been an entire absence of concrete evidence. Fortunately that evidence is now in hand and at last it is possible to present a complete account of this interesting rust and to offer explanations of the apparent rarity of its critical telial stage and the failure to recognize its haploid phase.

Thus far the telia of *Chrysomyxa Empetri* appear to have been found but three times — (a) by E. Rostrup (11) in Greenland, (b) by G. Lagerheim (9) near Tromsö, Norway, (c) by Axel Blytt (Jørstad 7) in Norway. So, regarding the occurrence of the telial stage, Sydow (13) expresses an opinion from which there has been so far no dissent, namely, "Diese wird jedenfalls nur sehr selten ausgebildet." The correctness of that opinion is now open to question in view of the fact that in June 1935, at about the time spruce buds were breaking, I discovered telia on *Empetrum nigrum* in great abundance at two stations, about 70 miles apart, on the south shore of the River St. Lawrence in the Province of Quebec — near Metis and Trois Pistoles, respectively. Revisiting these stations in June 1936 I found an equally heavy crop. Always they were the first sori to mature and only towards the end of their functional period did uredia begin to appear in large numbers. They remained active about two weeks, at the end of which time the leaves bearing them rapidly withered and their sori became no longer recognizable. It is also significant that the cultures recorded in Table 2, below, manifested the same phenomena. Judging, therefore, from these experiences, it is quite possible that telia are not rare and that they would be located in many places if the search were properly timed. They should be looked for on overwintered foliage during a brief period in the spring or early summer, according to the climate of the respective localities. To these records I would add my discovery of telia in a collection made by Professor Roland Thaxter on Mt. Washington, N. H., July 3–9, 1886 (Reliquiae Farlowianae, no. 691).

My research interest in *Chrysomyxa Empetri* was actually first aroused by the chance finding, on August 25, 1933, a profuse display of an unknown, orange-colored *Peridermium* on *Picea glauca* at Metis Beach, Quebec. *Empetrum nigrum,* rusted with *C. Empetri* in its uredo-stage, formed a carpet under the affected spruces. This association and the absence of other Chrysomyxa-susceptible hosts suggested that the unknown *Peridermium* belonged to the hitherto unrecognized haploid phase of *C. Empetri.* If this were true then there must have been a crop of telia on the associated *Empetrum.* I returned to the same spot on

June 30, 1934, but found that the new foliage of the spruces was already showing severe infection; the telial stage, on *Empetrum,* if there had been one, was past, leaving few tangible remains. The most that I could discover of telia, were what appeared to be exhausted sori on browned, withered leaves. The next year I arrived three weeks earlier and at an especially opportune date because the first telia to mature were just being exposed through the rupture of epidermis overlaying them. The abundance of telia was so great that upturned shoots of *Empetrum* appeared as though liberally sprinkled with miniature, yellow cushions. Yet at the end of another two weeks the telia were exhausted and for the main part had disappeared. With so much telial material available, culture experiments were at once initiated.

These experiments have comprised a total of 38 culture tests, as follows — A. From *Empetrum nigrum* to *Picea*: (1) 22 tests on *Picea glauca* in 1935; (2) 6 tests on *Picea glauca* in 1936; (3) 2 tests on *Picea rubens* in 1935. B. From *Picea glauca* to *Empetrum nigrum*: (4) 8 tests in 1935–6.

The results of the experiments listed under "A" above are recorded in Table 1. The tests were made on vigorous young trees 8 to 25 feet in height, located on the margin of pasture lands at "Green Gables," Leggatt's Point, Quebec, five miles distant from the source of the inoculum. *Empetrum nigrum* and *Chrysomyxa* rusts of all kinds were absent from the immediate neighborhood. The experiments were protected in part by screens during the period of incubation. All of the cultures were highly successful, as is shown by a photographic reproduction of one of them in plate 202. The rest of the foliage of the experimental and adjacent spruces remained entirely free from infection.

The results of the experiments listed under "B" above are recorded in Table 2. The cultures were made at the Arnold Arboretum, Harvard University, on a vigorous mat of *Empetrum nigrum* growing in partial shade between two greenhouses — the only examples of living *Empetrum* in the Arnold Arboretum. This mat of *Empetrum* originated from seed sent from Kew Gardens, England and planted in 1930 by Mr. William H. Judd, Propagator at the Arnold Arboretum, under no. 727–30. Eight shoots of the mat were inoculated — (a) 4 with aeciospores collected from natural infections at Metis Beach, Quebec and (b) 4 with aeciospores collected from my cultures on *Picea glauca* at Leggatt's Point, Quebec, in 1935. Seven of these experiments gave positive results, the infections producing a few uredia and many telia. No rust appeared elsewhere on the mat.

TABLE 1

CHRYSOMYXA EMPETRI FROM EMPETRUM NIGRUM TO PICEA, USING FIELD-COLLECTED TELIAL INOCULUM

(a) Experiments 1–5, 7–12; on *Picea glauca.*

Inoculations made June 15, 1935 on new shoots of spruce partly expanded.
Spermogonia first observed June 28, 1935.
Peridermia appeared early in August.
Materials were harvested August 24, 1935.
Heavy infection in all experiments, and on needles of current season only. Thus in no. 4 nearly all of the approximately 500 needles of the current season inclosed in the inoculation tube became infected and produced peridermia.
Controls remained free from infection.
Specimens preserved in Herb. J. H. Faull under no. 12,702 (1–5, 7–12).

(b) Experiments 13–24; on *Picea glauca.*

Inoculations made June 20, 1935 on new shoots of spruce partly expanded.
Peridermia appeared early in August.
Materials were harvested August 24, 1935.
Heavy infection in all experiments, and on needles of current season only.
Controls remained free from infection.
Specimens preserved under no. 12,703 (13–24).

(c) Experiments 25–29; on *Picea glauca.*

Inoculations made June 21, 1936 on new shoots of spruce quite fully expanded.
Peridermia appeared about August 1, 1936.
Materials were harvested August 9, 1936.
All experiments showed infection though not nearly so abundant as in the experiments of 1935. The youngest needles only of the current season became infected.
Controls remained free from infection.
Specimens preserved under no. 12,877 (25–29).

(d) Experiment 6; on *Picea rubens.*

Inoculation made June 15, 1935 on new shoots of spruce partly expanded.
Spermogonia first observed June 28, 1935.
Peridermia appeared early in August.
Material was harvested August 24, 1935.
Heavy infection.
Controls remained free from infection.
Specimens preserved under no. 12,702 (6).

(e) Experiment 30; on *Picea rubens.*

Inoculation made June 21, 1936 on new shoots of spruce quite fully expanded.
Peridermia appeared about August 1, 1936.
Material was harvested August 9, 1936.
Rather light infection and on youngest needles only of current season.
Controls remained free from infection.
Specimens preserved under no. 12,877 (30).

TABLE 2

CHRYSOMYXA EMPETRI FROM PICEA GLAUCA TO EMPETRUM NIGRUM, USING FIELD-COLLECTED AECIOSPORES IN EXPERIMENTS 1–4, AND CULTURE-PRODUCED AECIOSPORES IN EXPERIMENTS 5–8, FROM EXPERIMENTS RECORDED UNDER (A) AND (B), TABLE 1. (1, 2, 3)

No.	Date of inoculation	First appearance of sori	Kinds of sori	No. of needles infected	Date harvested
1	3.IX.35	28.XI.35 30.IV.36	II III	1 1	30.IV.36 7. V.36
2	3.IX.35	No infection			
3	3.IX.35	30.IV.36	III	4	13. V.36
4	3.IX.35	30.IV.36	III	4	5. V.36
5	3.IX.35	30.IV.36	III	15	13. V.36
6	3.IX.35	30.IV.36	II,III (4)	18	11. V.36
7	3.IX.35	X.35 30.IV.36	II II,III (5)	6 11	28. V.36 5. V.36
8	3.IX.35	X.35 30.IV.36	II III	1 7	13. V.36 13. V.36

(1) All controls remained free from infection.
(2) These experiments were conducted at the Arnold Arboretum, Harvard University, Jamaica Plain, Mass.
(3) The aeciospores used as inoculum were obtained at Metis Beach, Quebec.
(4) Four uredia and 50 telia.
(5) One uredium, 18 telia, 10 sori undetermined.

Chrysomyxa Empetri (Pers.) Schroeter in Kryptog. Flora Schles. **3**[1]: 372 (1887). (II). O, I, II, III.

Uredo Empetri Pers. (in litt.) in Moug. and Nestl. Stirp. Crypt. Vogeso-Rhen. no. 391. (1813). No description.
Uredo Empetri Pers. ex DC. in Fl. Fr. **6**: 87 (1815).
Caeoma Empetri (Pers.) Link in Willd. Sp. Pl. **6**[2]: 16 (1825).
Erysibe Empetri (Pers.) Wallr. in Fl. Crypt. Germ. **2**: 199 (1833).
Thecopsora Empetri (Pers.) Karst. in Bidr. Finlands Nat. Folk, **31**: 143 (1879).
Chrysomyxa Empetri (Pers.) Rostr. in Meddel. om Grönland, Kjøbenhavn, **3**: 536 (1888).
Melampsoropsis Empetri (Pers.) Arthur in Résult. Sci. Congr. Bot. Vienne, p. 338 (1906).

O. Spermogonia on needles of current season, amphigenous, uniseriate, conspicuous, yellowish, then reddish-brown, slightly elevated, aparaphysate, immersed, subepidermal, 135–162 μ broad and 108–135 μ deep, averaging 145 $\times$ 125 μ; spermatiophores unbranched; living spermatia subglobular to ellipsoid, 5.0–7.0 × 5.5–10.0 μ; extruded in colorless, sticky liquid.

I. Aecia (peridermia) on needles of current season, yellow, amphigenous, uniseriate, on pale yellowish-discolored portions of affected needles, elliptical to subcircular in transverse section, 0.5–1.5 mm. in greatest width and 0.5–2.0 mm. high; peridium colorless, rupturing at the apex; peridial cells polygonal, elongate vertically, not imbricate or but slightly so, in a single layer, 19–54 × 32–76 μ, with outer walls smooth, about 1 μ thick, and inner walls rather coarsely verrucose, 4–6 μ thick; aeciospores yellow, ellipsoid or ovoid, rarely subspherical, 22–32 × 27–54 μ, averaging about 27 × 42 μ; walls of aeciospores closely and rather coarsely verrucose, the warts more or less dehiscent at maturity, hyaline and 1.5–2.0 μ thick.

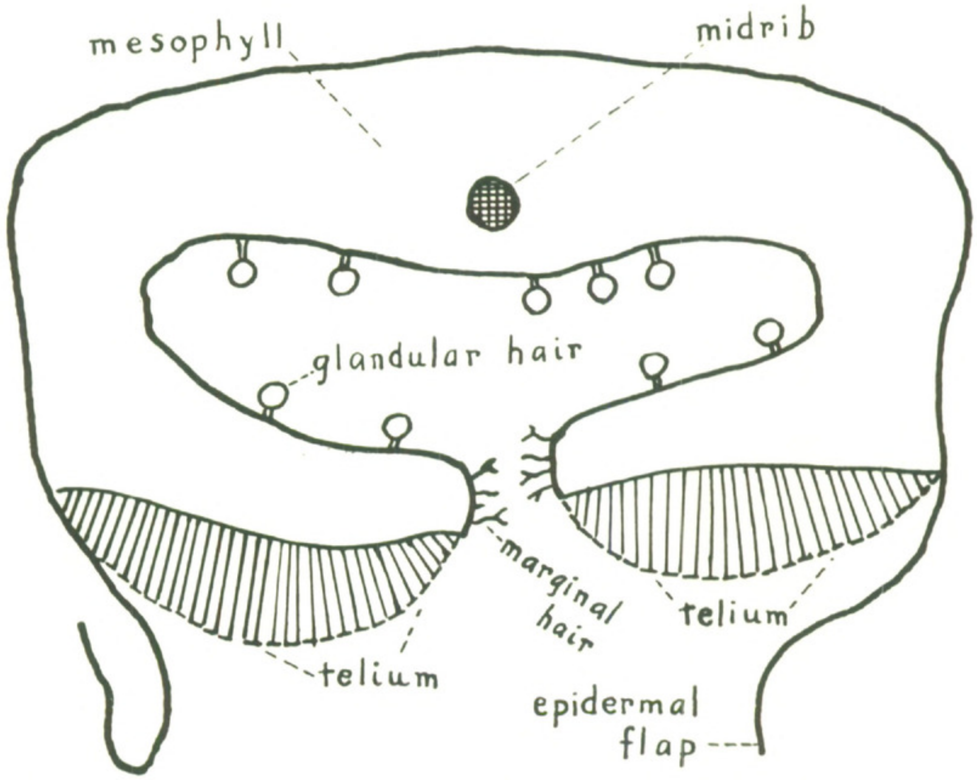

FIGURE 1. Schematic drawing of transverse section of a leaf of *Empetrum nigrum* with two mature telia of *Chrysomyxa Empetri*. Note ruptured epidermis over each telium. Drawn to scale. × 100.

II. Uredia epiphyllous, one to few on a leaf, pustular, convex before rupture, becoming concave as spores are discharged, subepidermal, round or elliptical to linear, 0.2–2.0 mm. in major axis; peridium distinct, adherent to overlying epidermis which ruptures widely at maturity, 15–17 μ thick; peridial cells in a single layer, angular, thin-walled, 10–20 μ in diameter; urediospores orange, catenulate, with intercalary cells, pulverulent, ellipsoid, ovoid or subglobose, 21–27 × 27–48 μ, averaging about 25 × 35 μ; walls of spores hyaline, closely and rather coarsely verrucose, 1.5–2.0 μ thick.

III. Telia in spring or early summer on overwintered leaves, epiphyllous, one or two to few on a leaf, yellow, cushion-shaped, waxy, subepidermal, overlying epidermis widely rupturing at maturity, exposed surface yellow to straw-colored, relatively smooth, compact and fine-textured, subcircular to mostly much elongate, often nearly as long as the leaf itself, 0.5–3.0 mm. in major axis; no peridium; teliospores with yellow contents, catenulate, 3 to 6 in a chain, without intercalary cells, smooth, thin-walled, 18–21 × 19–24 μ. The teliospores germinate promptly *in situ* at maturity, beginning with those that are terminal and the basidia soon form a dense velvety nap. Basidia pale yellow, slightly curved to strongly arched, typically 4-celled, 7–8 μ in diameter and up to 65 μ in length. Basidiospores with yellow contents, very thin-walled, subglobose to slightly ellipsoid, varying from 10–15 μ in diameter but usually about 12 μ.

Hosts and Distribution

O, I. *Picea glauca* (Moench) Voss* in Quebec (nature and cultures).
Picea rubens Sarg.* in Quebec (cultures).

II. *Empetrum nigrum* L. in United States (Me., N. H., Vt.*, N. Y.), Alaska*, Canada (B. C., Alta.*, Que., N. S.*), Newfoundland*, Greenland, Latvia, Norway, Sweden, Denmark, Great Britain, France, Germany, Austria, Czechoslovakia, Hungary, Switzerland, Poland, Finland, Russia (in Europe), Siberia, Japan.
Empetrum atropurpureum Fern. & Wieg.* in Quebec.
Empetrum Eamesii Fern. and Wieg.* in Newfoundland.
Empetrum rubrum Vahl in Falkland Islands.

III. *Empetrum nigrum* L. in Greenland, Norway, Quebec*, New Hampshire*.

Type locality.

Vosges, France; uredia on *Empetrum nigrum*. (Moug. and Nestl., Stirpes Cryptogamae Vogeso-Rhenanae, no. 391. 1813.)

Illustrations.

Grove in British Rust Fungi, p. 311, fig. 235; Arthur in Manual of the Rusts in United States and Canada, p. 31, fig. 41.

*New records.

EXSICCATI

Moug. and Nestl. Stirp. crypt. vogeso-rhen. 391; Fuckel Fg. rhen. 2697; Sydow Myc. germ. 971; Sydow Ured. 143, 2394; Thuemen Myc. univ. 1044; Racib. Myc. polon. 149; Smarods Fg. latvici 70; Eriksson Fg. par. scand. 177; Linhart Fg. hung. 342; Reliq. Farl. 691.

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EXPLANATION OF PLATES

PLATE 202

Chrysomyxa Empetri (Pers.) Schroet. Inoculation experiment No. 17 of 1935. *Picea glauca* (Moench) Voss inoculated with telial material from *Empetrum nigrum* L. collected June 20, 1935. Date of inoculation June 20; harvested August 24, 1935. × 1. Herbarium J. H. Faull no. 12,703 (17).

PLATE 203

Chrysomyxa Empetri on *Picea glauca*. Natural infection. Metis Beach, Quebec. August 25, 1935. × 1. The leafless internodes of 1934 indicate a very heavy rust infection in 1934. Herbarium J. H. Faull no. 12,704.

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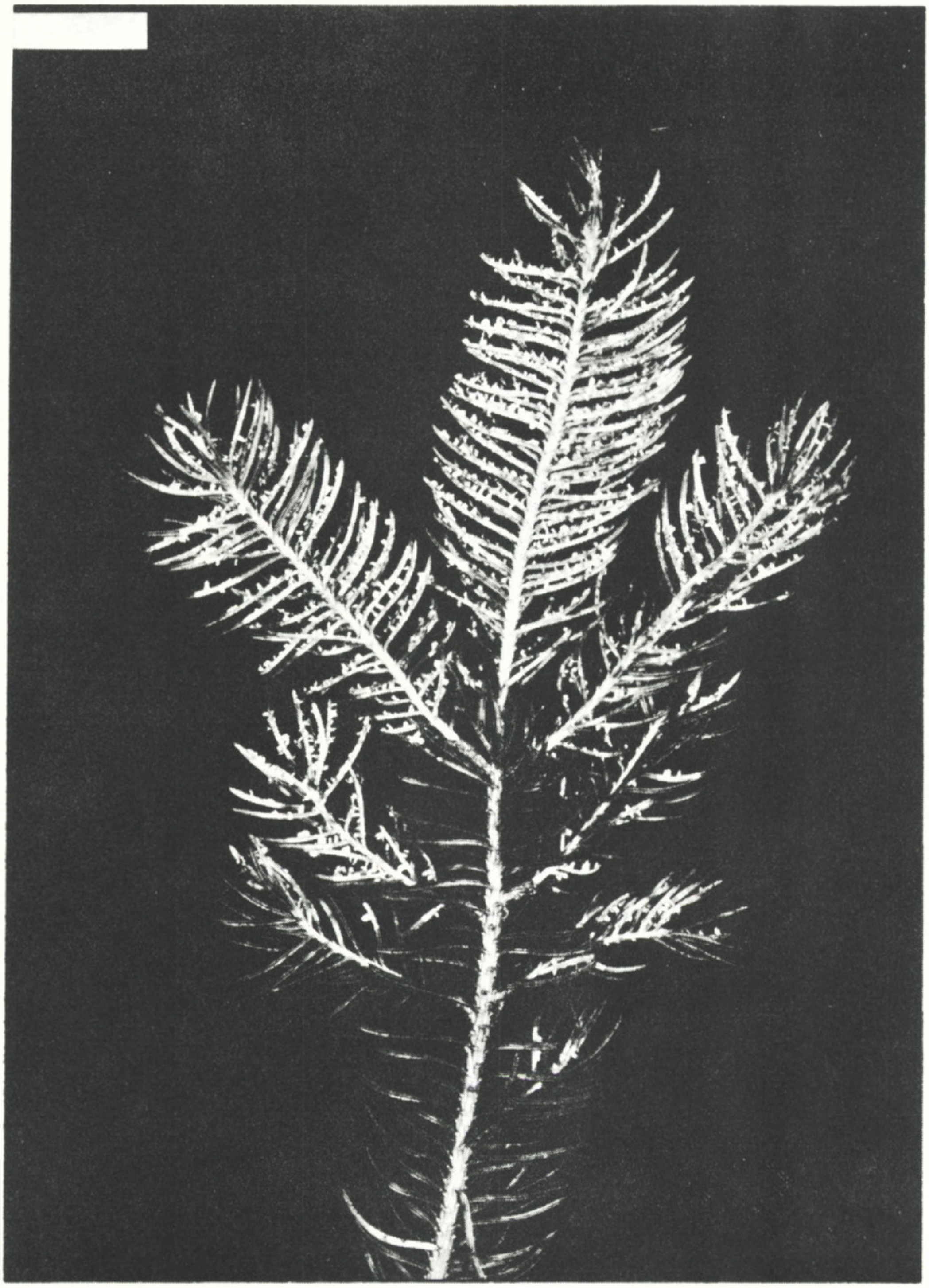
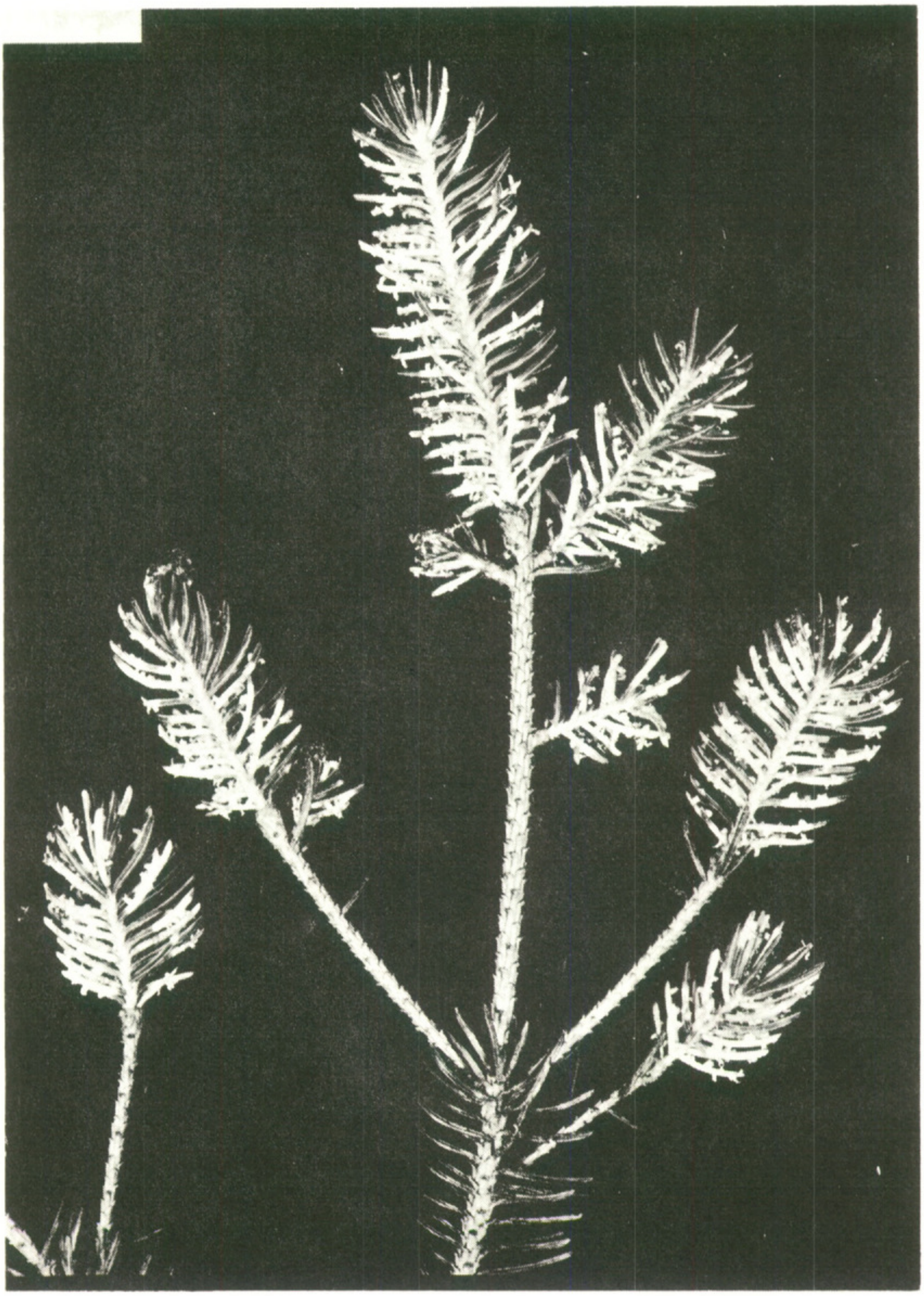


Chrysomixa Empetri—A Spruce Infecting Rust

FULL-TONE — MERIDEN



Chrysomixa Empetri—A Spruce Infecting Rust