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### **Rhododendron-Mildews in Scotland**

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**Abstract.** – The occurrence of two powdery mildews on *Rhododendron* spp. in cultivation in Scotland, one belonging to the genus *Erysiphe* and the other to *Sphaerotheca*, is documented. Tables of hosts, photographs of symptoms and diagnostic information on these mildews is offered, and a new record of *Erysiphe rhododendri* KAPOOR is reported.

### **Introduction**

Diseases caused by powdery mildews of *Rhododendron* spp. in cultivation have recently attracted attention in a wide variety of popular horticultural publications, e. g. *Rhododendron* (SMITH, 1981; ANON. 1984 a & b). In their review of plant troubles at Wisley during the period 1980–83 BROOKS & KNIGHTS (1984) noted that a powdery mildew of *Rhododendron* had been received for identification in 1980, yet “there is some doubt as to the positive identification of the causal agent although both *Erysiphe cruciferarum* OPIZ ex JUNELL and *Sphaerotheca pannosa* (WALLR.: FR. LÉV.) have been implicated”.

Mildews of *Rhododendron* spp. had been studied in Edinburgh as early as 1956 (HENDERSON, pers. comm.) and since 1973 intensively by the present author. This contribution is an attempt to clarify the situation in Scotland, and a host list for these mildews is offered.

### **History**

In July 1969 a powdery mildew was located on plants of *Rhododendron zoelleri*\*) in a greenhouse at the Royal Botanic Garden, Edinburgh. The plants were from a batch introduced from New Guinea as seedlings the previous July. The live material, introduced under WOODS 1895 (68.1631)\*\*) was collected in the Rawlinson Mts, (19 vi 1968; 1340 m), Morobe District, and was housed with other seedlings from the Mt Dayman area, Milne Bay District, including WOODS 2646 which also showed evidence of mildew infection. WOODS 2646 on maturing and/or flowering was shown to be a

\*) Authorities for the host plant are indicated in the charts.

\*\*) Two digits followed by a four digit number throughout the text refers to the Accession Number, Royal Bot. Garden, Edinb.

mixture of taxa in the Sect. *Vireya*; the seedlings in fact represented at least four different species, viz. *R. christiana* (76.0829), *R. leptanthum* (76.0831), *R. macgregoriae* (74.1325) and *R. rhodoleucum* (68.2180). The infected leaves in the cryptogamic herbarium in Edinburgh under Woods 2646 have been re-determined by both P. J. B. Woods and G. Argent (pers. comm.) as belonging to *R. christiana* and *R. macgregoriae*, and some larger leaves as those of *R. inconspicuum*. Samples of these early mildew infections were kept in the Edinburgh herbarium as "*Oidium*".

On finding these infections, a more extensive search was made of the living stocks of Ericaceae and mildew was also found on *R. leptanthum* (Woods 2099), Henderson & Watling (24 vii 1969); on *Vaccinium ambylandrum* (Woods 2620), also introduced from New Guinea as a seedling, (*Oidium* sp., 7 vii 1969, Henderson); *Agauria salicifolia* (Burt 4654) from Malawi introduced to the Edinburgh Garden in 1967 (*Oidium* sp., 7 vii 1969, Henderson) and several *Erica* spp., eg. *E. oatsii*; see Table I. Mildew on *Erica* spp. in fact had been known intermittently for some time (on *E. pageana*, 22 xi 1956, Henderson 2906; on *Erica* sp., 30 xi 1956, Henderson 2910). Later in 1969 plants of *R. laetum* (67.0214), raised from seed collected in New Guinea by Slemmer in 1967, also succumbed to mildew. All infected material was removed from the premises and forwarded to the Plant Health Inspectorate. Material from the original expedition in 1968 came not only to Edinburgh but went also to the garden of the late M. Black Esq. of Grasmere, Westmorland; he reported having seen some of the leaves of his Malesian *Rhododendron* seedlings showing symptoms of scorch but no mildew was communicated to the Plant Inspectorate.

In 1973 *R. christi* (Woods 3166 & 3180A), not previously infected, showed hypertrophied shoots and development of a powdery mildew. These plants had also been collected during August 1968 in New Guinea (Murray Pass, Mount Albert Edward area, Goilala subdistrict, Central district) at an altitude around 2745 m.

It was at this time that the present author undertook an extensive and lengthy study of what was potentially a hazard to the *Rhododendron* stocks at the Royal Botanic Garden, Edinburgh. On re-examination of all the available material housed in E it soon became apparent that two distinct entities existed, one a species of *Oidium* s. str. with large conidia sometimes reaching 50  $\mu$ m long and primarily infecting leaves and shoots, and found on *Erica*, *Agauria*, *Rhododendron zoelleri* and *Vaccinium ambylandrum*, and a small-spored systemic fungus classifiable in the genus *Oidiopsis* with smaller conidia generally less than 25  $\mu$ m long and infecting buds of *Rhododendron laetum* (67.0214) and *R. christi*. No cleistothecia were found, or have since been found, but an *Erysiphe*-type would be

expected in the first, and a *Mycosphaera* or *Sphaerotheca* in the second. It was the *Oidiopsis* which caused concern.

The *R. christi* plants showing symptoms were isolated from the main collections and treated with a rota of Mil Col (Tetramethylthiuram disulphide), fernacol (4-(2-Chlorophenylhydrazon)-3 methyl-5-iso-azolme) and benomyl (Methyl 1-butylcarbamyl-2-benzimidazole carbamate) with some success but in 1978, one year after the whole ericaceous stock was transferred to new, although very crowded conditions, a massive outbreak was noted; indeed over fifty plants were infected covering 30 collection numbers and seven taxa. A drastic reduction of the collections was undertaken.

Several authorities were consulted but because of the absence of cleistothecia the mildews remained unidentified although the mildew on *Erica* spp. had been filed in the herbarium (E) under the name *Oidium ericinum* ERIKSS. Reference to a key to conidial states of powdery mildews by BOESEWINKEL (1979), however, supported the separation of the two mildews on *Rhododendron*. The separation was based on differences in size of the conidia and whether internal fibrosin bodies were present in the conidia. Later BOESEWINKEL (pers. comm.) identified the two as *Erysiphe cruciferarum* OPITZ ex JUNELL and *Sphaerotheca pannosa* (WALLR.: FR.) LÉV. respectively; these determinations were later published (BOESEWINKEL, 1981).

### Host-distribution

BOESEWINKEL kindly examined eighteen collections of *Rhododendron* and allied taxa and identified *Erysiphe* on seven and the *Sphaerotheca* on eleven. The former is in fact far commoner in the collections in Edinburgh, the seeming disparity above being caused only by the selection of material sent to BOESEWINKEL; more of the systemic taxon was collected it being more obvious, impressive and worrying. The total number of Ericaceae which have been attacked in the glasshouses by the *Erysiphe* (Table I) now totals 73 and by the *Sphaerotheca* 18 and 2 hybrids (Table II).

*Erysiphe cruciferarum* as understood by BOESEWINKEL has a wide host range spanning many genera in the Ericaceae and he is probably correct in considering that the Malesian rhododendrons became infected after introduction. Inoculation experiments (McKENZIE MUNRO, pers. comm.) have not, however, been successful in cross-inoculating the mildew from *R. christianae* (75.2617) onto *Brassica napus*.

*Sphaerotheca pannosa*, in contrast, is usually found only on *Rhododendron* Sect. *Vireya* (Table II). This was even the case when infected plants were growing close to other *Rhododendron* spp. belonging to other sections. *S. pannosa* is common on cultivated

roses and was found in the glasshouses on newly introduced *Rosa omeiensis* ROLFE from China (Sino-British C. C. 812481; WAT. 14314). BOESEWINKEL (1981) suggests that although introduction with exotic seedlings is possible, the *S. pannosa* found on *Rhododendron* in Edinburgh was probably derived from local infection of cultivated roses or the like. However, *Sphaerotheca* from rose did not infect Malaysian *Rhododendron* spp. and the mildew derived from *R. laetum* (67.0214) did not infect roses in an attempted reciprocal cross; this work has not been continued.

### Outdoor non-Malesian Rhododendrons

No *Erysiphe cruciferarum* has so far been found on the outdoor collections in Edinburgh but material kindly supplied by A. BROOKS (WAT. 18079) from Wisely, agreed with the *Erysiphe*, as did material from Penzance (Boskenna nurseries, legit R. G. PARIS, 10. iii 1982), from Gigha, Kintyre (iv 1984) and the Edinburgh Royal Botanic Garden's sister property at Benmore, Argyll (legit A. P. BENNELL; BH 677, 678 & 681 in E; 24 iv 1984).

The material from outdoor rhododendron in W England and further localities in England and Wales is the subject of a study by plant pathologists of the Ministry of Agriculture, Fisheries and Food. More recently, deciduous azaleas in the *R. japonicum* series have been shown to be susceptible (COOK & EVANS, pers. comm.; SLADER, 1976).

*Rhododendron cinnabarinum*, *R. campylocarpum* HOOKER, *R. forrestii* (BALFOUR f. ex) DIELS., *R. fortunei*, *R. griffithianum* and *R. thomsonii* HOOKER have all been considered at risk (ANON. 1984a): see Table III. The Benmore material was on *R. cinnabarinum* hybrids including "Lady Rosebery" and "Lady Chamberlain" and the Gigha material on *R. "cinnabarinum"*. The Boskenna material included a whole range of hybrids, including "Tortoiseshell" ("Champagne" & "Wonder"); the data is summarised in Tables I & III. Surface hyphae only, but probably of the same organism, were located on four further hybrids at Boskenna of which "Teal" and "CIS" were originally both from Eastern Scotland stocks.

The summer of 1984 was hot and dry, very conducive to mildew growth; favourable conditions therefore may explain the appearance of the mildew in Western Scotland where plants were also debilitated by *Diplodina eurhododendri* VOSS. and *Phoma rhododendri* COOKE; these were the first substantiated records of the *Erysiphe cruciferarum* on outside rhododendrons in Scotland.



### Extralimital collections

A. BAILEY and R. T. A. COOK kindly sent me mildew, also on *R. zoelleri* and originally from New Guinea, which had been found at Kew; this material agreed with *Erysiphe cruciferarum* (WAT. 17310 & 4). As the Royal Botanic Garden, Edinburgh already had exchanges of rhododendron material with Dr. P. VALDER, (University of Sydney, New South Wales) the opportunity was taken whilst the author was in Australia to examine collections of *Rhododendron* spp. there. VALDER was kind enough to make available mildewed material from both the University Botany Department glasshouses and from his own private collections. All this material also turned out to be *E. cruciferarum* and it extended the host range still further (see Table I; WAT. 18080-082 including *R. aurigeranum*, *R. championae*, *R. occidentale* grp. and hardy hybrid ("Yvonne" x "Lionel's Triumph"). VALDER (pers. comm.) had also seen the "same" mildew on *R. zoelleri* and *R. sessilifolium*.

Examination of herbarium material of susceptible rhododendrons from wild sources has failed to locate either of the mildews in Edinburgh, although perithecia of *Erysiphe rhododendri* KAPOOR have been located by my colleague B. J. COPPINS (pers. comm.; COPPINS 1438). *E. rhododendri* was described (KAPOOR, 1965) on leaves of an unidentified rhododendron from Sikkim, India. The Edinburgh collection was on *R. argyrophyllum* FRANCH. from Yunnan, China. This mildew is not relevant in the present study as a conidial state is not formed.

### Identification

BOESEWINKEL (1979) and later BRAUN (1984) showed it is possible to use the asexual stages in the identification of mildews and, as indicated above, BOESEWINKEL kindly identified the first group of isolates (in litt., 1981). The information he supplied has been used as a base-line and subsequently expanded.

The *Erysiphe* produces single, long, cylindrical, thin-walled, smooth, 1-celled meristem arthrospores,  $(22-25-45(-50.5) \times (8-11-17.5(-21) \mu\text{m})$  which lack internal fibrosin bodies. Variation in size depends apparently on the host (Fig. 1), and in some collections this variations is very large whilst in others it varies over only a small range. Germ-tubes are frequently produced and are always terminal. The conidiophores are 1-septate with a basal septum 1-2  $\mu\text{m}$  above the junction with the vegetative hyphae (6-6.5  $\mu\text{m}$  broad) and with foot cell < 40  $\mu\text{m}$  long. The accompanying mycelium is superficial and thin-walled throughout forming sporulating patches (Pl. 1, A-G).

In contrast, the *Sphaerotheca* produces chains (7+ cells) of relatively small ovoid conidia, (16–)17.5–27.5(–30)  $\times$  (8–)9.5–14.5  $\mu$ m with distinctive fibrosin bodies even detectable in herbarium material; variation in conidial size is never as great as in *Erysiphe* (Fig. 1) and is fairly constant for a single host (Fig. 2). Few germ-tubes were seen but when present were always terminal. The conidiophores are 1–2 septate, long and slender, 75–125(–150)  $\times$  6–8.5  $\mu$ m with the basal septa being 4–5  $\mu$ m above the long foot-cell (< 80  $\mu$ m). The accompanying mycelium is a mixture of thin-walled and thicker walled hyphae the latter often hair-like and (100–)200–450  $\times$  4–5  $\mu$ m. The vegetative mycelium is inter- and intracellular, inducing hypertrophication of the host tissues, and stunting (Pl. 1, H & Pl. 2).

Both mildews produce multilobed appressoria, possibly more lobed in the former taxon.

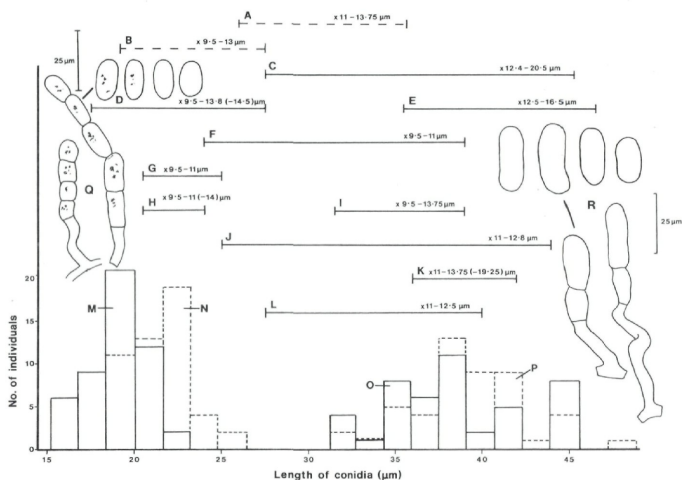


Fig. 1. Range of variation in isolates of *Erysiphe* and *Sphaerotheca*: A. *Brassica oleracea*, WAT. 12664. – B. *Rosa canina*, WAT. 163. – C. *Rhododendron leptanthum*, WOODS 2099. – D. *R. christi*, WOODS 3180A. – E. *Ceratostema*, 76.2364 (ARGENT). – F. *Vaccinium ambylandrum*, WOODS 2620. – G. *R. laetum*, 67.0214 (SLEUMER). – H. *R. macgregoriae*, WOODS 2642. – I. *Agauria salicifolia*, BURTT 4654. – J. *R. rhodoleucum*, WOODS 2646. – K. *Erica oatsii*, 66.1912 (BRYDEN). – L. *Diplycosia heterophylla*, 68.0665 (WOODS). – M. *R. santapau*, 72.1413. – N. *R. aurigeranum*, WOODS 40. – O. *Cavendishia complectens*, 75.1969. – P. *R. stenophyllum*, 69.2546. – Q. Conidia & conidiophores of *Sphaerotheca* on *R. christi*, WOODS 3180A. – R. Conidia & conidiophores of *Erysiphe* on *R. stenophyllum*, 67.2546.

## Symptoms

The *Erysiphe* is superficial on leaves and shoots (Pl. 1, A–G), causes spots on and discoloration of leaves in Malesian rhododendrons and sometimes on young, rapidly growing shoots; bad infections occasionally produce leaf-drop. In hardy *Rhododendron* spp.

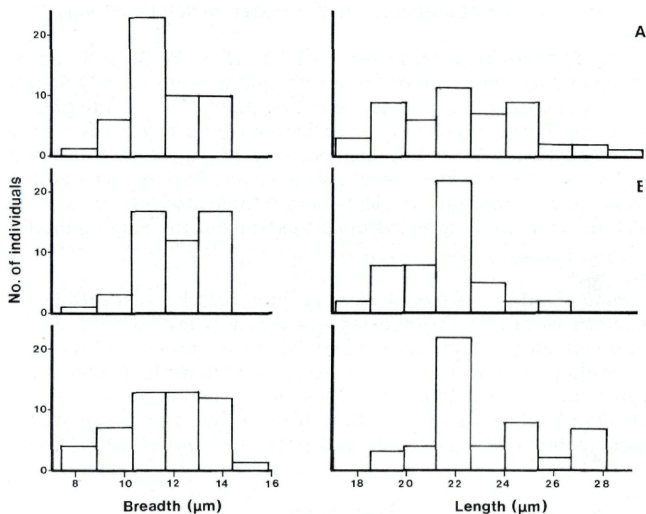


Fig. 2. *Sphaerotheca* on *Rhododendron christi*: Variation in breadth and length of conidia in different collections of *Rhododendron christi*: A. WOODS 2997. – B. WOODS 3193. – C. 67.3168 (WOODS).

of the *R. cinnabarinum*, *R. campylocarpum* and *R. ponticum* groups, and hybrids thereof, leaf-bronzing and leaf-blotch occur. Infection can be suspected by the appearance of yellow blotches on the leaves when they are viewed from the upper surface; on the lower surface of the leaves a white cobweb-like growth is found beneath these blotches and this occasionally becomes powdery. The blotches on the upper surfaces darken and often develop a purplish margin although only a slight reddening may be seen with mild infections. Premature yellowing follows although usually the mildew is confined to older leaves which are already in an advanced state of maturity. However, severe infection in Malesian *Rhododendron* spp. can lead to premature leaf-drop, and if coupled with adverse soil

conditions and/or presence of other harmful fungi complete defoliation follows.

In only one species, *R. brookeanum*, has blistering of the under leaf-surface been observed (Pl. 1, c). Infection of non-foliar structures is uncommon in rhododendrons although it has been found in *R. burtii*. However, *Agauria* seed-heads have frequently been found to support conidiophores (Pl. 1, E) as have senescing flower-buds in *Erica* spp.; the conidiophores in the latter develop amongst the hairs.

The *Sphaerotheca* is systemic (Pl. 1, H & Pl. 2) and causes spotting and discoloration of the leaves, and in many cases leaf-fall and complete defoliation of the shoot or plant. The conidiophores develop on both upper and lower leaf-surfaces especially where prior distortion of the leaf has been observed. Highly infected unrolled buds may produce leaves with a small kink or twist on one or other, or both margins; the leaf-margin then almost forms a small whorl. In more badly infected buds the leaf-outline may be totally destroyed if it develops at all; premature bud-fall has been noted in these cases.

*Rhododendron macgregoriae* is particularly susceptible to *Sphaerotheca* and in this species entire shoots may die (Pl. 2, H). Usually infected shoots can be identified in the absence of the tell-tale conidiophores as the infected shoot becomes swollen, often more deeply wine-coloured than uninfected shoots, and much more etiolated. Conidiophores have in addition been found on flower-buds, flowers (petals and sepals) and seed-pods of *R. chiristi* (Pl. 2, C-E).

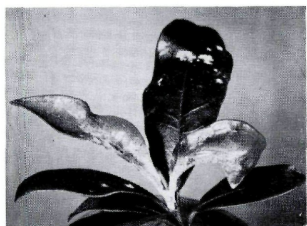
## Discussion

Initially it was a total surprise that the conidial structures of neither of the Edinburgh mildews agreed with any of the taxa described previously on ericaceous hosts; it was even more of a surprise when Dr. BOESEWINKEL's determinations were received, viz. *Erysiphe cruciferarum* and *Sphaerotheca pannosa*. The former is common in Scotland on crucifers; material in E ranges from collections on *Capsella bursa-pastoris* (L.) MEDIC. (HENDERSON 4872 & WAT. 14343), *Iberis umbellata* L. (WAT. 11824), *Sinapis arvensis* L. (WAT. 9893) and *Sisymbrium officinale* (L.) SCOP. (WAT. 7010; WAT. 14363) to the cultivated *Lunaria annua* L. (WAT. 16531), Swede (*Brassica napus* L.) (WAT. 14170), Turnip (*B. rapa* L.) (WAT. 14306 & 14171)

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Plate 1: *Erysiphe*. – A. *Rhododendron zoelleri* 68.1631. – B. *R. zoelleri*. 4 years later. – C. *R. brookeanum*, 69.0955. – D. *R. stenophyllum*, 67.2546. – E. *Agauria buxifolia*, 75.1103, infected seed capsules. – F. *Cavendishia complectens*, 75.1969. – G. *Agapetes variegata*, 75.1313. – *Sphaerotheca*: H. *R. aurigeranum* × *R. laetum*.

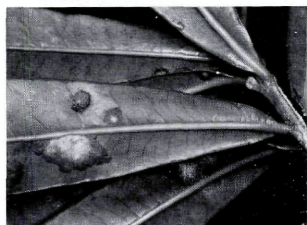




A



B



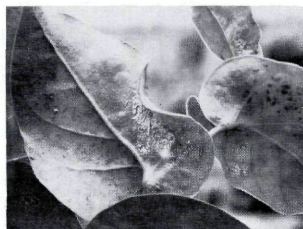
C



D



E



F



G



H

and Brussels sprouts (*Brassica oleracea* L.) (WAT. 12660 – see Chart I). Whereas material is also available in E on *Meconopsis horridula* Hook. f. & THOMAS (HENDERSON 9599) and cultivated Shirley poppies (*Papaver*) (HENDERSON 4871) both in the Papaveraceae; BOESEWINKEL (1980) lists members of the Fumariaceae and Geraniaceae also as hosts, and Ericaceae. The Edinburgh collections were the first records on species of *Rhododendron*.

*Sphaerotheca pannosa* has a rather different host range and *Rhododendron* appears to be the only generic host common to the *Erysiphe*. Thus although this mildew is found on many collections of wild (*Rosa canina* L.) and cultivated roses in Scotland (material in E; see Fig. 1 and Table I), BOESEWINKEL (1981) indicates as host not only *Rosa*, but also *Punica* and *Prunus* in the Rosaceae, and *Forstythia* (Oleaceae), *Eucalyptus* (Myrtaceae) and *Lycium* (Mangoliaceae).

Several species of Erysiphaceae occur on Ericaceae, both in the wild and in cultivation, but many records will have to be re-examined in the light of BOESEWINKEL's observations (1980; 1981). *Microsphaera alni* DC. ex WINT., especially as *f. vaccini*, is often recorded in plant pathology texts (PIRONE, 1970; WEISS, 1950; EGLITIS, GOULD & JOHNSON, 1967) as the causal agent in mildew of *Rhododendron*. Although recorded from N America this species has not as yet been found in the British Isles.

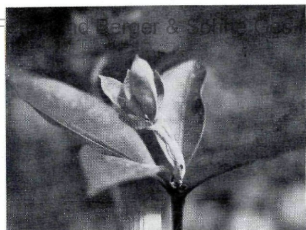
BRAUN (1984) has recently discussed the N American *Microsphaera* spp. including *M. vaccini* (SCHW.) COOKE & PECK (= *M. alni* f. *vaccini* (SCHW.) SALM.) in addition to the new *M. azaleae* BRAUN; the former occurs on a whole range of species in *Andromeda*, *Chiogenes*, *Epigaea*, *Gaultheria*, *Gaylussacia*, *Kalmia*, *Ledum*, *Lyonia*, *Menziesia* and *Rhododendron*, and the latter on *Rhododendron* only; *M. vaccini* is recorded on the same genera by HIRATA (1966) including both azaleoid rhododendrons\* and two species included in the present study. *Microsphaera rhododendri* (JACZ.) BUNKINA, although not validly published, can be recognised as the same as *M. azaleae*, as can the nomen nudum *M. penicillata* from *rhododendri* JACZ. (BRAUN, 1984). Other powdery mildews on Ericaceae are *Podosphaera myrtilina* (SCHUB.: FR.) KUNZE & SCHMIDT on *Vaccinium*

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\* = *Rhododendron* series *Azalea* = *Rhododendron* subgenus *Pseudoanthrodendron* SLEUMER.

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Plate 2: *Sphaerotheca*. – A. *Rhododendron laetum*, 67.0214, young apical shoot. – B. *R. santapauli*, 72.1413. – C.-E. *R. christi*, 68.2541: C. Lateral shoots below flower stalk. – D. Death of apical shoot, infected lateral shoots. – E. Infected leaf-stalk. – F.-H. *R. macgregoriae*, 68.1154: F. Infected seed-capsule. – G. Infected flowers. – H. Infected and dying side-shoots.



A



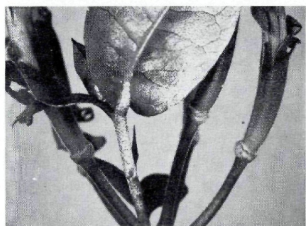
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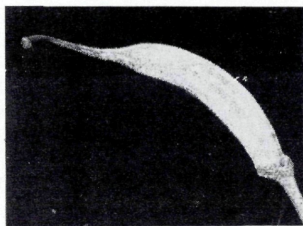
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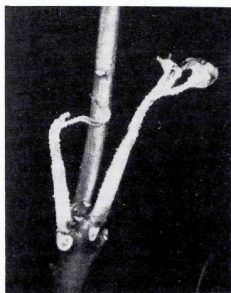
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*myrtillus* L., *V. vitis-idaea* L., *V. uliginosum* L. and *Oxycoccus* spp., and *P. major* (JUEL) BLUMER on *V. uliginosum*. *P. oxycanthae* (DC.) de BARY has been recorded from Alaska on *Vaccinium uliginosum* (WEISS, 1950) and *Phyllactinia corylea* PERS.: KERSK. from N America on *V. stamineum* L. agg. Both these last mildews probably would now be referred to segregate species, as would the entry of *Podosphaera leucotricha* (ELL. & EV.) SALMON, a fungus in its strict sense normally parasitic on rosaceous hosts. Indeed the records of *Podosphaera* probably all refer to either *P. myrtillina* or *P. major*. The record of *Phyllactinia* above and *P. suffulta* (REBENT.) SACC. on *Rhododendron ponticum* in USSR and on *R. albrechtii*, *Tritomodon* and *Tripetaleia* in Japan noted by HIRATA (1966) require further assessment. *Phyllactinia suffulta* is usually taken as a synonym of *P. guttata* (WALLR.: FR.) LÉV., a mildew found on frondose trees such as birch (*Betula*) and hazel (*Corylus*).

One hundred years ago ERIKSSON described *Oidium ericinum* on *Erica* spp. Material agreeing with ERIKSSON's description and BLUMER's later information and illustration (1933; 1967) has been found on several S African *Erica* spp. in Edinburgh (Table I). Material on *E. oatsii* when submitted to BOESEWINKEL was considered by him (pers. comm.) to be *Erysiphe cruciferarum*. Both *E. communis* (WALLR.) LINK and *E. polygoni* DC. have also been recorded on *Erica* spp., in the United States by WEISS (1950) and HIRATA (1966) but as these names have been used to cover a whole series of mildews even those on *Rhododendron*, eg. *R. nudiflorum* (L.) TORR. and *R. occidentale* from N America (WEISS, 1950), caution must be exercised. Many now independent mildews have previously been subsumed under aggregate names (JUNELL, 1967); see also *Erysiphe polyphaga* HAMMARL. (*nomen nudum*) on *Calluna* and *Erica* in HIRATA (1966). If the *Rhododendron* mildew in Edinburgh, and indeed Britain, with large conidia is a host specific strain of *E. cruciferarum* or a distinct species, a possible link might be sought amongst these North American finds.

## Conclusion

With the use of a fungicidal spray programme, inspection and spatial isolation or destruction of infected plants the systemic mildew (*Sphaerotheca*) was kept under control. After infection of a limited number of taxa during the period 1977-79 many more species of *Rhododendron* became infected. Production of conidiophores seemed to coincide in 1977 and 1978 with the winter months and this may be related to the semi-dormant state of *Rhododendron* spp. under glass which at the latitude of Edinburgh are subject to extremely low light conditions on winter days. By an



even more vigilant inspection, now every three months and more frequently in winter, and destruction of infected plants, the *Sphaerotheca* has been eliminated; it has not been seen since. Sporadic and small outbreaks of *Erysiphe cruciferarum* continue but can be controlled by fungicidal spray; these infections probably represent re-infections from other sources even from within the glasshouse system where the occasional conidiophore may still be found on *Erica* spp. and *Cavendishia*.

### Acknowledgments

I would like to thank my colleagues A. P. BENNELL and B. J. COPPINS for their help during this survey and to H. J. BOESEWINKEL who determined the original collections. R. HOLLANDS assisted in the preparation of the charts and tables, and P. J. B. WOODS and G. C. G. ARGENT checked the data on the host-plants involved.

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## Abbreviations used

- + information supplied by B. J. COPPINS.  
 \* = Material examined by BOESEWINKEL.  
 BH = A. P. BENNELL, Herbarium in E. Fresh collections sent in for examination.  
 Wat. = R. WATLING, Herbarium in E. Herbarium material examined only.  
 LAE = Department of Forestry, Division of Botany, Lae, Papua New Guinea.  
 WEI = Wau Ecological Institute, Morobe District, Papua New Guinea.

Table I: Hosts of *Erysiphe cruciferarum*

Species	Date first recorded	Conidia-size in $\mu\text{m}$
<i>Brassica oleracea</i> L.:		
WAT. 12664		26–35.75/11–13.75
<i>Agapetes stenantha</i> (SCHLTR.) SLEUMER		
WOODS 2521 (76.2042)	1981	
<i>A. variegata</i> D. DON ex G. DON		
Chamberlain 106 (75.1313)	1977	(see Pl. 1, G)
<i>Agauria salicifolia</i> (LAM.) HOOK. f.		
*BURTT 4654 (67.0288)	1969	31.5–39/9.5–13.75
75.0905 (JENDA)	1979	41–44/13–15.5
<i>A. buxifolia</i> (LAM.) CORDEM		
75.1103 (ARGENT)	1979	(see Pl. 1, E)
<i>Cavendishia bracteata</i>		
(RUIZ & PAVÓN ex JAUME SAINT HILAIRE)		
HOER.		
76.2376 (ARGENT)	1981	
<i>C. complectens</i> HEMSLEY		
75.1969, ex Univ. Calif.	1977	32–39/11.2.–19.2.: (see Pl. 1, F)
<i>C. strobilifera</i> (H. B. K.) HOER.		
76.2376 (ARGENT)	1981	
76.2352 (ARGENT 521)	1985 +	
<i>Ceratostema</i> sp.		
76.2364 (ARGENT)	1984 +	35.8–46.5/12.5–16.5
<i>Costera endertii</i> J. J. SMITH		
80.1197 (ARGENT)	1981	30–38–48/12.5–16.5
<i>Dimorphantha dryophila</i> SLEUMER		
73.0420 ex LAE	1982	
<i>D. megacalyx</i> SLEUMER		
WOODS 1865 (68.1531)	1982	
<i>Diogenesia amplectens</i> (SLEUMER) SLEUMER		
76.2376 (ARGENT 724)	1981	
<i>Diplycosia heterophylla</i> BL.		
WOODS (68.0665)	1981	
KERBY 309 (77.3559)	1981–82	27.5–40/11–12.5
<i>D. soror</i> BECCARI var. <i>nuda</i>		
SLEUMER		
WOODS 2647 (68.2181)	1981	
<i>Diplycosia</i> sp.		
*BURTT & MARTIN 5400 (67.2555)	1980	32–46.5/14.5–17.4 46.5–50.5(–55)/13–16

Species	Date first recorded	Conidia-size in $\mu\text{m}$
<i>Diplycosia</i> sp. 80.1348 (ARGENT)	1981	33–34/13–14
<i>Diplycosia</i> sp. 80.1351 (ARGENT)	1984 +	42–46.5/12.5–16.5
<i>Diplycosia</i> sp. 80.1355 (ARGENT)	1981	42–46.5/12.5–16.5
<i>Diplycosia</i> sp. 80.1412 (ARGENT)	1981	33–34/12–12.5
<i>Disterigma</i> sp. 76.2391 (ARGENT)	1981	32–43.5/14.5–18(–23.2)
<i>Erica axilliflora</i> BARTL. 76.1430 ex Kirstenbosch Bot. Gdn.	1980	30–43.75/11.25–11.5
<i>E. formosa</i> THUNB. 83.0429	1984 +	
<i>E. glomiflora</i> SALISB. 83.0430	1984 +	
<i>E. mammosa</i> L. 76.1446 ex Kirstenbosch Bot. Gdn.	1984 +	31.25–45/12.5–17.5
<i>E. nudiflora</i> L. 76.1450 ex Kirstenbosch Bot. Gdn.	1977	33–49.5/13.75–18
<i>E. oatesii</i> ROLFE *66.1912 (BRYDEN)	1969	36–42.5/11–13.75(–19.25)
<i>E. pageana</i> L. BOLUS No accession number	1956	(see text)
<i>E. pelviformis</i> SALISB. 76.1447 ex Kirstenbosch Bot. Gdn	1979	
<i>E. plukenetii</i> L. 83.0435 ex Kirstenbosch Bot. Gdn.	1984 +	32.5–50/12.5–20
<i>E. subdivaricata</i> BERG. 76.1461 ex Kirstenbosch Bot. Gdn	1979	
<i>Gaultheria codifolia</i> H. B. & K. HERKLOTS 146 (74.1664)	1981	
<i>G. domingensis</i> URB. HERKLOTS 135 (73.0612)	1985 +	33–35 long
<i>Macleania glabra</i> HOER. HERKLOTS 142 (73.0614)	1981	
<i>Rhododendron aurigeranum</i> SLEUMER *ex VALDER, New South Wales: WAT. 18080	1979	27–38.5/10–13.5
<i>R. brachyanthum</i> Franchet hybrids Penzance TEAL: BH 749	1984	(see Table III) Mycelium only
<i>Rhododendron brookeanum</i> LOW ex LINDL. 69.0955 (ALLEN): WAT. 17307	1980	22–33/10–11 (see Pl. 1, C)
<i>R. burtii</i> P. WOODS BURTT & MARTIN 5549 (67.2565)	1981	34–35/12–12.5
<i>R. championae</i> HOOKER *ex VALDER, New South Wales WAT. 18085		26.5–40.5/11–13.75
<i>R. christi</i> FOERSTER KORES 1487	1981	

Species	Date first recorded	Conidia-size in $\mu$ m
<i>R. christianae</i> SLEUMER		
73.1628 (CRUTTWELL)	1981	34-35/11.5-12
WEI 1487 (75.2617)	1981	28-33/10-11
<i>R. cinnabarinum</i> HOOKER (hybrids)		(see Table III)
Ben More		
Lady Chamberlain	1984	31-40/13-17
Lady Rosebery	1984	Mycelium only
Gigha	1984	32-44/13-14(-18)
Penzance		
Lady Chamberlain: BH 742	1984	Mycelium only
Bodnant Yellow: BH 744	1984	
<i>R. dichroanthum</i> DIELS. (hybrids)		(see Table III)
Penzance		
CIS: BH 747	1984	39/19
Ripe Corn: BH 742	1984	Mycelium only
Tortoiseshell Champagne	1984	Mycelium only
Tortoiseshell Wonder	1984	39/19
<i>R. dielsianum</i> SCHLTR.		
WEI 1497 (75.2618)	1984 +	
* <i>R. griffithianum</i> WIGHT (hybrids)		(see Table III)
Yvonne X Leonel's Triumph		
ex VALDER, New South Wales:		
WAT. 18082		23.8-31.5/8.25-9.5
Penzance		
Britannia: BH 748	1984	
<i>R. inconspicuum</i> J. J. SMITH		30.25-35.75/8-11.5
<i>R. lanceolatum</i> RIDL.		
*BURTT & MARTIN 5514 (67.2562)	1973	35-38.5/12.8-17.5
<i>R. leptanthum</i> F. v. MUELLER		
WOODS 2099 (68.1742)	1969	
<i>R. ? lochae</i> F. v. MUELLER	1977	29-35/8.5-9.5
<i>R. macgregoriae</i> F. v. MUELLER		
(see also footnote)	1977	
*72.2178 (ARGENT)		28.5-38.5/10-12
*72.2179 (ARGENT)		30-33/8-9.5
61.4242 (SLEUMER)		35-36/12-12.5
WOODS 1565 (68.1160)		37-38/12-12.5
WOODS 2646A (68.2197)		24.75-42.6/11-16.5
WOODS 3203 (68.2559)	1969	27.5-42.5/12.3-19.3
<i>R. aff. macgregoriae</i>	1977	38.5/12-12.5
<i>R. maxwellii</i> L. S. GIBBS	1985 +	26-40.5/8.5-14.5
80.1235 (ARGENT)		
<i>R. nervulosum</i> SLEUMER		
80.1157 (ARGENT)	1981	33-35/10.5-12
<i>R. occidentale</i> A. GRAY		
ex VALDER, New South Wales:		
WAT. 18081	1974	33-35/9.5-11
<i>R. orbiculatum</i> RIDL.		
72.1704 (ALLEN)	1981	
76.2590 (ARGENT)	1981	37-38/11



Species	Date first recorded	Conidia-size in $\mu\text{m}$
76.2848 (BUXTON)	1981	36–39/13–13.5
<i>R. pneumonantherum</i> SLEUMER		
BURTT & MARTIN 5380 (67.2550)	1981	33–35/12–12.5
<i>R. ponticum</i> L. unnamed hybrids		
ex BROOKS, Wisley: WAT. 18079	1981	
<i>R. retivenium</i> SLEUMER		
80.1233 (ARGENT)	1981	37–38/12–12.5
80.1149 (ARGENT)	1981	
<i>R. rhodoleucum</i> SLEUMER		
Woods 2646 (68.2180)	1973	(22–)23.5–42/11–12.8(–16.5)
<i>R. sessilifolium</i> J. J. SMITH		
74.1757 ex VALDER	1981	33–34/11–11.5
<i>R. stenophyllum</i> STAPP.		
*BURTT & MARTIN 5322 (67.2546)	1977	32–48/11–17.5 (see Pl. 1, D)
79.2888 COLLENETTE		32–43.5(–49.5)/13–15 (–20)
80.1190 (ARGENT)		34–35.5/11–12
<i>R. veitchianum</i> HOOKER		
ex VALDER, New South Wales:	1974	24.5–31.5/11–12.5
WAT. 18084		
<i>R. verticillatum</i> LOW ex LINDL.		
SINCLAIR & ARGENT 123 (82.0822)	1984 +	
<i>R. zoelleri</i> WARB.		
*WOODS 1895 (68.1631)	1969	(see Pl. 1, A + B)
*WOODS 2283 (68.1967)	1977	32–48/13–14.5
WOODS 2773 (68.2251)	1977	(26)30–36/11–12(–14)
55.0409 (van STEENIS)	1984 +	35–52/14.5–18
ex BAILEY, Kew, 2 coll.: WAT.		25.5–34/9–11
17304 & 17310		24–40/10–12
<i>Spyrospermum</i> cf. <i>sodirei</i> (HER.)		
A. C. SMITH	1979	25.5–27.5/11–16.5
76.2390 (ARGENT)		
<i>Vaccinium acrobacteatum</i> K. SCH.		
WOODS 2102 (68.1745)	1981	32–33/12–12.5
<i>V. ambylandrum</i> F. v. MUELLER		
*WOODS 2620 (68.2164)	1969	(24–25/12.5–13.75 (26–27.5/9.5–11 (24.75–39/11–16.5
<i>V. bancanum</i> MIQ.		
SINCLAIR & ARGENT 73 (82.0772)	1982	32–43.5/14.5–20
<i>V. filiforme</i> (J. J. S.) SLEUMER		
80.1411 (ARGENT)	1984 +	35.5–42.5/12.5–16.5
<i>V. monanthum</i> RIDL.		
KERBY 15 (77.3328)	1984 +	
<i>V. reticulatovenosum</i> SLEUMER		
WOODS 1863 (68.1529)	1980	35–43(–47)/13–21
<i>V. tenerellum</i> SLEUMER		
KERBY 395 (77.3625)	1984 +	44–50/13.5–18
<i>V. varingiaefolium</i> (BL.) MIQ.		
*WOODS 1027 (68.0857) as <i>Agapetes</i>	1977	
<i>Vaccinium</i> sp.		
80.1193 (ARGENT)	1981	

Table II. Hosts of *Sphaerotheca pannosa*

Species	Date first noticed	Conidia-size in $\mu\text{m}$
<i>Rosa canina</i> L. WAT. 163		19.25–27.5/9.5–13.5
<i>Rosa</i> (cultivated floribunda): WAT. 14151		19.25–27.5/11–15
<i>Rhododendron armitii</i> F. M. BAILEY WOODS 1727 (68.1423)		
<i>R. aurigeranum</i> SLEUMER *WOODS 40(66.1921)	1977	20.5–25.5/9.5–12.8
<i>R. aurigeranum</i> SLEUMER $\times$ <i>R. laetum</i> J. J. SMITH	1977	20–24/8–12.8 (see Pl. 1, H)
<i>R. christinae</i> SLEUMER *WOODS 2646B (76.0829)	1973	27.7–32/11.2–12.8
*STANTON 71.2124	1973	16–22.5/9.5–12.8
<i>R. christinae</i> $\times$ <i>R. aurigeranum</i> *76.0989 WEI Hybrid 247 $\times$ Hybrid 254	1977	17.5–22.5/8–12.8
<i>R. christi</i> FOERSTER *WOODS 3180A (68.2630)		
*WOODS 3166 (68.2538)	1973	(see Table II & Pl. 2, C–E)
*WOODS 2997 (68.2484)		(17.5–27.5(–30)
*WOODS 3193 (68.2541)		(9.5–13.8–14.5)
*67.3168 (MASON)		
<i>R. cruttwellii</i> SLEUMER *HERKLOTS 4A (65.0268)	1977	22.5–28.5/9.5–14.5
WOODS 2721 (68.2219)		
WOODS 2799 (68.2272)		
<i>R. intranervatum</i> SLEUMER	1973	19–24/9.5–14.5
*BURTT & WOODS 2829 (66.2876)	1977	19–22.5/8–9.5
<i>R. javanicum</i> (BL.) BENN. *71.2125 ex STANTON	1973	17.5–22.5/9.5–12.8
<i>R. laetum</i> J. J. SMITH *67.0214 (SLEUMER)	1973	20.5–25/9.5–11 (see Pl. 2, A)
<i>R. leptanthum</i> F. v. MUELLER $\times$ <i>R. gracilentum</i> F. v. MUELLER WOODS 1971 (68.1453)	1973	17.5–22.5/9.5–12.8
<i>R. lochae</i> F. v. MUELLER 51.0365 ex Kew	1973	19.25–22/8.5–9.5
67.0480 ex San Francisco (Golden Gate Park) as <i>R. commonae</i> .	1973	
<i>R. luteosquamatum</i> SLEUMER $\times$ <i>R. herzogii</i> WARB. 75.2623 ex WEI	1977	20.8–25.5/9.5–12.8
<i>R. macgregoriae</i> F. v. MUELLER WOODS 1559 (68.1154)		(see Pl. 2, F–H)
*WOODS 2642 (68.2177)		
*WOODS 2966A (68.2473)		20.5–24/9.5–11(–14)
*WOODS 3072 (68.2641)		
*WOODS 3203 (68.2559)	1973	
<i>R. orbiculatum</i> RIDLEY *BURTT & MARTIN 5363 (67.2468)	1977	25.5–26/12.8–14.5

Species	Date first recorded	Conidia-size in $\mu\text{m}$
<i>R. rugosum</i> LOW ex HOOK. f. 71.0912 (BARON)	1977	
<i>R. santapau</i> SASTRY & al. COX & HUTCHINSON 459 (72.1413)	1977	16–20.8/9.5–12.8 (see Pl. 1, B)
<i>R. searleanum</i> SLEUMER *SEARLE 39 (74.1176)	1973	24/12.8
<i>R. zoelleri</i> WARB. *67.2430 ex Lae	1977	
*WOODS 2773 (68.2251)	1981	22.5–28.8/11–12.8
<i>Rhododendron</i> sp. BUXTON 115 (76.2693) from Mt Kinabalu, Sabah	1979	22–25/7.8–10

Table III: Parentage of *Rhododendron*-Hybrids infected by *Erysiphe cruciferarum*

Cultivar	Cross
Aurora	"Kewense" $\times$ <i>R. thomsonii</i> HOOKER f.
Bodnant Yellow	* <i>R. cinnabarinum</i> HOOKER (yellow form) $\times$ "Royal flush" (orange form)
Britannia	"Queen Wilhelminia" $\times$ "Stanley Davies"
Champagne	see Tortoiseshell below
CIS	"Loders White" $\times$ "Fabia"
Exbury Naomi	"Aurora" $\times$ <i>R. fortunei</i> LINDLEY
Fabia	* <i>R. dichroanthum</i> DIELS. $\times$ <i>R. griersonianum</i> BALFOUR f. & FORREST
Goldsworth Orange	* <i>R. dichroanthum</i> $\times$ <i>R. fortunei</i> subsp. <i>discolor</i> (FRANCHET) CHAMBERLAIN
Kewense	* <i>R. griffithianum</i> $\times$ <i>R. fortunei</i>
Lady Chamberlain	*( <i>R. cinnabarinum</i> var. <i>roylei</i> (HOOKER) HORT. $\times$ * <i>R. cinnabarinum</i> ) $\times$ "Royal Flush" – orange form
Lady Rosebery	*( <i>R. cinnabarinum</i> var. <i>roylei</i> $\times$ * <i>R. cinnabarinum</i> ) $\times$ "Royal Flush" – pink form
Lionel's Triumph	<i>R. lacetum</i> FRANCHET $\times$ "Exbury Naomi"
Loders White	<i>R. fortunei</i> LINDLEY $\times$ * <i>R. griffithianum</i>
Ripe Corn	"Goldsworth Orange" $\times$ "Exbury Naomi"
Royal Flush	* <i>R. cinnabarinum</i> $\times$ <i>R. maddenii</i> HOOKER
Queen Wilhelminia	* <i>R. griffithianum</i> WIGHT $\times$
Stanley Davies	unknown parentage
Teal	<i>R. brachyanthum</i> FRANCHET $\times$ <i>R. fletcherianum</i> DAVIDIAN
Tortoiseshell (Champagne & Wonder)	"Goldsworth Orange" $\times$ <i>R. griersonianum</i>
Wonder	see Tortoiseshell above
Yvonne	"Aurora" $\times$ <i>R. thomsonii</i>

\* Susceptible partner: see text

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