Identification and Host Range of Powdery Mildew of Begonia

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ABSTRACT

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The intrageneric and intergeneric host range of two races of *Oidium begoniae* was investigated. The races are morphologically identical, but only one race has the ability to infect the Aphrodite cultivars of *Begonia* × *hiemalis* (Rieger elatior begonias). In the intergeneric host range study, *Sphaerotheca fuliginea* from pumpkin (*Cucurbita mixta* 'Spooky') infected begonia cultivar Schwabenland Red but grew slowly and had conidial states different from those of *O. begoniae*. Begonia species resistant to both races of *O. begoniae* had lower optimum temperatures for infection and hyphal growth.

Additional key words: *Erysiphe cichoracearum, Erysiphe polyphaga, Microsphaera tarnavschii*

Several species of powdery mildew occur on various species of begonias. Most commonly reported is *Oidium begoniae* Puttemans, which has conidial characteristics like those of *Erysiphe polygoni* DC, *Microsphaera* spp. or *Uncinula* spp. type (12). Recently *Microsphaera tarnavschii* Eliade was suggested as the perfect state of *O. begoniae* (3). *O. begoniae* var. *macrospora* (Putt.) De Mendonca and De Sequeira has been important in Europe in recent years (2). Its conidia are 34–72 × 9–23 μm, whereas conidia of *O. begoniae* are 20–36 × 13–17 μm. The perfect state of the large spored species is probably *Microsphaera begonia* Sivanesan (8). *Erysiphe polyphaga* Hammarlund was identified on a wide range of hosts, including begonia (4). *E. polyphaga* has not been seen on begonia since Hammarlund's original paper, is not *O. begoniae* Putt., and may be a dubious taxon (1). *Erysiphe cichoracearum* DC ex Merat has also been reported on begonia in California and Canada (5).

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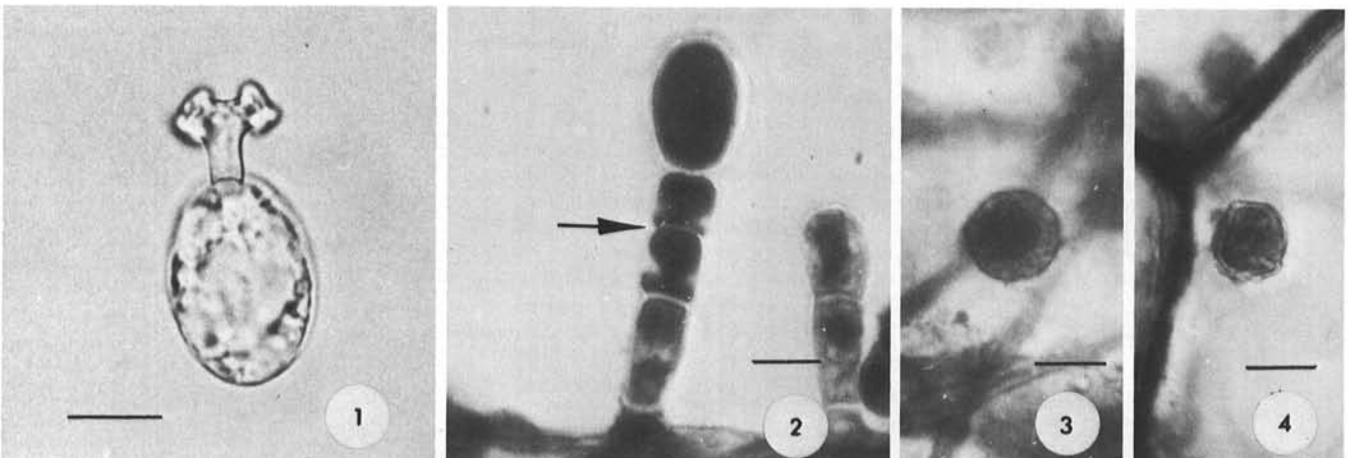
Strider (11) and Powell and Quinn (6) reported a change in the intraspecific occurrence of powdery mildew on elatior begonias in the United States, manifested in the "loss of immunity" of the Aphrodite cultivars of Rieger begonia (*Begonia* × *hiemalis* Fotsch). The change in host range suggested that new races or species of the pathogen were present. In previous investigations concerning intraspecific occurrence, no detailed pathogen comparisons were done (11).

In this study, we procured two begonia mildews separable by host range. We investigated the identity and the morphology of the pathogens and the susceptibility of several cultivars and species of begonias, by using simultaneous inoculation and incubation experiments. We also searched for additional hosts in an attempt to identify sources of primary inoculum that may influence outbreaks in greenhouses.

MATERIALS AND METHODS

Rieger begonia stock plants were grown in a greenhouse in which no begonia powdery mildew has been present. In the intrageneric host range study, leaves from these plants were inoculated in the laboratory with one of the races of *O. begoniae* and were placed in double petri plates. Double petri plates are two stacked plastic plates with a hole between them to insert the leaf petiole through. The top plate holds the leaf blade and the bottom plate contains water.

The leaves were incubated at 21 C for 2 wk and rated on a 0–3 scale for degree of



Figs. 1–4. *Oidium begoniae.* **(1)** Conidium showing germination and lobate appressorium. **(2)** Conidiophore bearing single elliptical conidium. The distal cell of the conidiophore had recently divided (arrow); the new distal cell is the next day's conidium. **(3)** Normal haustorium. **(4)** Shriveled, encapsulated haustorium. Each bar represents 10 μm. Whole mounts stained with Trypan blue.

Table 1. Host range of begonia powdery mildew race 2 and susceptibility of begonias to powdery mildews from other hosts

Source of inoculum	Fungus	Test host	Result[a]
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Antirrhinum majus* L.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Chrysanthemum × morifolium* Ramat.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Cucumis sativa* L.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Cucurbita mixta* Pang.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Kalanchoe blossfeldiana* Poelln.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Lathyrus latifolius* L.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Petunia hybrida* Hort.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Phlox paniculata*	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Rosa* sp.	negative
Begonia × hiemalis (Schwabenland Red)	*Oidium begoniae* Putt. (race 2)	*Zinnia elegans* Jacq.	negative
Acalypha rhomboidea Raf.	*Erysiphe cichoracearum* DC ex Merat	Schwabenland Red	negative
Aesculus glabra Willd.	*Uncinula flexuosa*	Schwabenland Red	negative
Ambrosia trifida L.	*E. cichoracearum*	Schwabenland Red	negative
Cucurbita mixta Pang.	*Sphaerotheca fuliginea* (Schlect. ex Fr.) Poll.	Schwabenland Red	positive
Helianthus annuus L.	*E. cichoracearum*	Schwabenland Red	local lesions
Ligustrum vulgare L.	*Microsphaera pencillata* (Wallr. ex Fr.) Lev.	Schwabenland Red	negative
Parthenocissus sp.	*U. necator* (Schw.) Burr.	Schwabenland Red	negative
Plantago major L.	*E. cichoracearum*	Schwabenland Red	negative
Polygonum sp.	*E. polygoni* DC	Schwabenland Red	negative
Quercus robur L.	*M. pencillata*	Schwabenland Red	negative
Rosa sp.	*S. pannosa* (Wallr. ex Fr.) Lev.	Schwabenland Red	negative
Syringa chinensis Willd.	*M. pencillata*	Schwabenland Red	negative
Taraxacum officianale A. Weber	*S. macularis* (Wallr. ex Fr.) Lind.	Schwabenland Red	negative
Trifolium pratense L.	*E. polygoni*	Schwabenland Red	negative
Viburnum sp.	*M. pencillata*	Schwabenland Red	negative
Vitis sp.	*U. necator*	Schwabenland Red	negative
Zinnia elegans Jacq.	*E. cichoracearum*	Schwabenland Red	local lesions

[a] Positive = mildew from source host was able to infect and complete its life cycle on the test host. Local lesions = fungus penetration triggered rapid host response, killing both the invaded host cell and the mildew, resulting in minute necrotic lesions. Negative = fungus was unable to infect test host.

infection (0 = mildew unable to complete life cycle on host, 1 = a few slow-spreading minute lesions, 2 = mildew easily observed but not present in quantity to kill leaf, 3 = mildew spreads and kills leaf in 2 wk). Conidia for morphological observations were obtained from both the greenhouse and double petri plate cultures.

Leaves for the intergeneric host range tests were brought in from outdoors or from greenhouses each time they were needed. We checked for natural contamination on these leaves by including uninoculated leaves in the incubation chamber.

Stock "cultures" of our two races were maintained on begonia leaves in double petri plates in incubators. All powdery mildew was originally collected from naturally infected plants in Franklin County, Ohio.

Interactions of temperature and resistance of selected begonia cultivars to *O. begoniae* were studied by using excised leaves grown in double petri plates. These leaves were inoculated with our race 2, grown in incubators at a constant temperature for 7 days, and then examined with a dissecting microscope equipped with an ocular micrometer.

RESULTS AND DISCUSSION

Powdery mildew on all begonias observed by us was caused by *O. begoniae* Putt. Identification was made partly on the basis of elliptical conidia (20–36 × 13–17 μm) and lack of crystalline fibrosin bodies. Most conidia germinated within 4

Table 2. Intraspecific host range of *Oidium begoniae* Putt.

Host	Disease index[a]	
	Race 1	Race 2
Begonia × hiemalis Fotsch		
'Aphrodite Cherry Red'	0	3
'Aphrodite Pink'	0	3
'Ballaleika' (Schwabenland Red)	3	3
'Baluga' (Schwabenland Red)	3	3
'Fantasy' (Aphrodite)	0	3
'Flambeau' (Aphrodite)	0	3
'Krefeld Orange' (Schwabenland Red)	3	3
'Nixe' (Schwabenland Red)	3	3
'Renaissance' (Schwabenland Red)	3	3
'Schwabenland Pink'	3	3
'Schwabenland Red'	3	3
Begonia × catalina Hort.	0	1
B. hispida Schott ex A. DC *cucullifera variegata* Irmsch.	2	2
B. imperialis Lem.	0	1
B. manicata Brogn. ex Cels *crispa*	1–2	1–2
B. massoniana Irmsch. 'Iron Cross'	2	2
B. oxyphylla A. DC	0	0
B. paralis Irmsch.	0	0
B. rex-culturum L. H. Bailey	2	2
B. schmidtiana Regel	0	0
Begonia × semperflorens-culturum Hort. 'Linda'	2	2
B. socatrana Hook. f.	3	3
B. sophie × cecille	0	0
B. thurstonii Hort. ex Kennedy	1	1
B. veitchii Hook. f. *carmine*	0	0
B. vellosiana	1	1
B. venosa Skan. ex Hook. f.	0	0
B. vitifolia Schott	0	1
Begonia × argenteo-guttata V. Lemoine	0	0
Begonia × richmondensis Hort.	0	0
Begonia × tuberhybrida Voss.	0–3[b]	3
B. curly zip Hort.	1	1
B. roulette (B. tiger kitten Hort. × *B. boutique* Hort.)	0	0

[a] 0 = death of mildew within 48 hr of inoculation without any sporulation; 1 = minute, slow growing colonies; 2 = small, visible colonies that do not cause death of host; 3 = fast spreading colonies at 21 C that lead to death of host.

[b] Variability due to difference in susceptibility of varieties of tuberous begonias.

Table 3. Growth of *Oidium begoniae* hyphae in micrometers after 7 days on selected species of begonia at various temperatures

Species or cultivar	12 C	15 C	18 C	21 C	24 C
Begonia × *hiemalis* 'Schwabenland Red'	···	730 c	···	1,401 a	545 d
Begonia × *hiemalis* 'Aphrodite Joy'	531 de[x]	765 c	1,001 b	1,357 a	827 c
B. semperflorens 'Charm'	424 ef	834 c	1,073 c	747 c	280 gh[y]
B. thurstonii	377 fg	364 fg	···	281 gh[y]	188 hi[y]
Begonia × *richmondensis*	212 hi[y]	355 fg	291 gh[y,z]	114 i[y,z]	111 i[y,z]

[x] Numbers followed by the same letter do not differ significantly according to Duncan's new multiple range test ($P = 0.05$).
[y] No sporulation observed.
[z] Growth stopped within 48 hr.

hr on glass even in low relative humidity (< 25%). Lobate appressoria (Fig. 1) and spherical haustorial complexes about 14 μm in diameter (Fig. 3) formed. This description of *O. begoniae* agrees with Zaracovitis' description (12).

If there are no air currents, chains of conidia on conidiophores will form even in low relative humidities (< 25%). We have observed, however, that conidia are usually borne singly in nature. Conidiophores are made up of a basal cell and a distal cell. Conidia were formed by division of the distal cell at the rate of one per day (Fig. 2). Sporulation occurs 4 days after inoculation and incubation at 21 or 24 C. These features are descriptive of fungi the perfect states of which are *Erysiphe polygoni, Microsphaera* spp. or *Uncinula* spp.

Sphaerotheca fuliginea (Schlect. ex Fr.) Poll. from pumpkin (*Cucurbita mixta* Pang. 'Spooky') was able to colonize the Rieger begonia cv. Schwabenland Red but grew considerably slower than *O. begoniae* (Table 1). *S. fuliginea* spread from single lesions over entire leaves after 3-mo incubation. *S. fuliginea* was identified by the conidial characteristics (including presence of fibrosin bodies), formation of conidia, size and shape of conidia, conidia in long chains, and the host on which it was found. It kept these characteristics through several transfers on begonia.

S. fuliginea also infects Kalanchoe and a wide variety of other hosts (1,10). However, previous reported attempts to infect begonia with the cucurbit mildew failed (1,9). In the past *S. fuliginea* was probably often identified as *E. cichoracearum* on cucurbits and begonias.

E. cichoracearum from zinnia (*Zinnia elegans* Jacq.) and sunflower (*Helianthus annuus* L.) produced local lesions in our study. These resulted from the rapid cell necrosis that followed penetration of the cell by the mildew and formation of undersized haustorial complexes (6–10 μm in diameter). These complexes were encapsulated by wall-like depositions (Fig. 4). A small amount of secondary hyphae were present in the local lesions. Other results of the intergeneric host range study were negative.

Although the search for an intergeneric host could continue, the primary source of inoculum for new mildew outbreaks is most probably infected begonias. Investigations are in progress to identify modes of pathogen survival that could result in infected plants showing no symptoms or perhaps only minute evidence of infection. Such situations exist for powdery mildews on rose and many other crops, where they often involve bud or stem tip infections (7).

The intrageneric host range of the two morphologically identical races confirms previously published differences in susceptibility between the Rieger begonias derived from either the Schwabenland or Aphrodite cultivars (Table 2) (6,11). In our extension of the intrageneric host range study, the parental stock of these begonias, *B. socatrana* and unknown tuberous begonias, also showed great susceptibility to both races studied. Some tuberous begonias are resistant to race 1. Thus, resistance of the Aphrodite cultivars to race 1 may be derived from its tuberous parent. This resistance is characterized by lack of haustorium formation. The rhizomatous *B. rex-culturum* Bailey and *B. semperflorens* Link and Otto are moderately susceptible to both races. On some species, such as *Begonia* × *richmondensis* Hort., both races of mildew penetrate and some hyphal formation takes place, but no sporulation occurs. In this reaction haustoria are shriveled and become encapsulated and no growth of hyphae is seen after 48 hr (Fig. 4). Species exhibiting this strong resistance had a hypodermal layer under the upper epidermis, which more susceptible species lacked.

In a test of representative cultivars and species, the relative degree of susceptibility of the begonias changed with temperature (Table 3). Species such as *Begonia* × *richmondensis* and *B. thurstoneii* Hort., considered highly resistant to both races at 21 C, are capable of sustaining growth longer than 48 hr and supporting sporulation of *O. begoniae* at lower temperatures. On moderately susceptible hosts (*B. semperflorens, B. rex-culturum*) that we tested, optimum temperature for mildew growth was 18 C. On highly susceptible Rieger begonias, 21 C is optimum for growth (Table 3). It appears that the more resistant the begonia, the lower the optimum temperature for mildew growth. Such a situation emphasizes the need to control temperatures when evaluating cultivar or species resistance toward a pathogen of this sort. Furthermore, test conditions should be similar to those normally occurring during production of the crop (17–21 C).

A cross between the resistant hypodermal cultivar Roulette (hyphal growth of 222 μm in 7 days at 21 C) and moderately susceptible nonhypodermal *B. imperalis* Lem. (1,061 μm) resulted in two moderately susceptible nonhypodermal offspring, Silver curl and Silver sheen (1,025 μm). This suggests that this resistance, which is not race specific, is apparently conveyed by one or more recessive genes. Attempts to incorporate such resistance to powdery mildew into *Begonia* × *hiemalis* will be difficult.

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