Fungal pathogens of the invasive riparian weed *Hedychium coronarium* from Brazil and their potential for biological control

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This paper gives an account about fungi collected during a survey in southern Brazil for pathogens of the riparian weed, *Hedychium coronarium*. This is a pantropical weed of the family *Zingiberaceae* which is exotic and aggressively invades wet ecosystems in Brazil. The surveys were conducted between July of 2004 and March of 2006 and resulted in a list of seven fungi. *Gonatophragmium mori*, *Leptosphaeria* sp., *Mycosphaerella hedychii*, *Pseudocercospora hedychii* and *Veronaea hedychii* sp. nov. appear to be pathogenic to *H. coronarium* and are fully described. *Curvularia lunata* var. *aeria* and *Chalara aurea* are considered to be of dubious pathogenic status and are only listed with minor comments. No previous surveys of pathogens of *H. coronarium* have been made in the native habitat (Himalayas) or in exotic situations. Such results are of importance for classical biological control. Superfluous introductions of fungal species as biocontrol agents can now be avoided in case they later appear in surveys in the centre of origin as they are clearly ineffective in controlling this weed in Brazil.

Key words: anamorphic fungi, ascomycetes, biological invasion, cercosporoid fungi, classical biocontrol, fungal survey, white ginger.

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Introduction

Hedychium coronarium J. Koenig (white ginger; Brazilian name – lírio do brejo, *Zingiberaceae*) is exotic to Brazil where it is a highly noxious invasive weed of wet habitats. The Himalayas are the probable centre of origin, although Madagascar is also mentioned as a possible centre of origin (Kissmann, 1997; Mabberley, 2002). It was possibly introduced to Brazil via ships carrying slaves from Africa (Ziller, 2000). This plant is widely dispersed in the littoral plains, and has become an aggressive invader in wetlands and in the understory of the Atlantic rain forest, mainly in the states of São Paulo, Paraná and Minas Gerais. In Minas Gerais this plant is a serious invader in the 'Estação Ecológica do Tripuí', a natural reserve created in 1978 to protect the habitat of the rare and evolutionary interesting invertebrate, *Peripatus acacioi* Marcus & Marcus (*Onychophora*). This animal has been dislodged from the lower plain areas where this weed occurs (Pedralli *et al*., 1997; Santos, 2004). The only native genus of *Zingiberaceae* in Brazil is *Renealmia* L.f. which is restricted to the Amazon basin (Souza and Lorenzi, 2005). According to Strauss *et al*. (2006) exotic plants distantly related to natives must be considered as potentially noxious invaders. This is the case of *Hedychium coronarium* in Brazil. Despite the lack of more detailed studies, the noxious effects of this plant can easily be observed (Pedralli and Meyer, 1996; Macedo, 1997; Santos *et al*., 2005). Recently, observations in protected areas in the states of Minas Gerais, Paraná and São Paulo confirm this statement.

The invasion of other species of *Hedychium* (viz. *H. gardnerianum* Ker-Gawl) in the native forests of Hawaii, La Reunion and New Zealand is well documented (MacDonald

et al., 1991; Williams *et al*., 2003; Loope *et al*., 2004; Asner and Vitousek, 2005). Information on the invasive status of *H. coronarium* is less well documented but this species is also widespread and noted as invasive throughout the tropics including Brazil (Santos, 2004) and particularly in island ecosystems (PIER, 2006).

The chemical and mechanical control of this plant in Brazil, as well as elsewhere, is not viable because its rhizomes are highly resistant and difficult to remove. The plant is also widespread and usually occurs in wetlands and along water courses where the use of herbicides is impractical and illegal. The only viable strategy that might be applicable to control *Hedychium* spp. invasions is biological control (Santos *et al*., 1998; Harris *et al*., 1999). Ellison and Barreto (2004) have mentioned the possibility of using fungi as biological control agents against *H. coronarium*. Anderson and Gardner (1999) and Anderson (2003) gave an account of the potential use of *Ralstonia solanacearum* to control *H. gardnerianum*. However, according to these authors the strain of *R. solanacearum* used against *H. gardnerianum* does not have potential to be used against *H. coronarium*.

More than 20 fungi have been recorded on *H. coronarium* worldwide (Bussaban *et al*., 2002; Farr *et al*., 2007), but there are no records from Brazil. The knowledge of the mycota on this plant in Brazil is of great relevance for biological control. If classical introductions of fungi from the centre of origin are considered in the future, this information would be of critical importance to allow avoiding superfluous introduction of fungi that are already present in Brazil without producing any significant impact on white ginger populations. This paper presents the results of the survey of fungal pathogens on *H. coronarium* in Brazil.

Materials and methods

The collecting procedure adopted during the survey was as described in Barreto (1991). The collecting trips occurred between July 2004 and February 2006. Information on some ad hoc collections that were made before the main survey work is also included. The survey covered a wide geographic area of central and southern Brazil including the states of Minas Gerais, São Paulo, Rio de Janeiro, Espírito Santo, Paraná, Santa Catarina, Rio Grande do Sul, Mato Grosso, Mato Grosso do Sul, Goiás, totalling more than 30,000 kilometers travelled.

The diseased parts of the plants suspected to be damaged by fungal pathogens were collected, dried in a plant press and taken to the laboratory. The isolation of the potential agents was performed by direct transfer of fungal structures to Petri dishes containing 15 mL of Vegetal Broth Agar (VBA) medium (Pereira *et al*., 2003), with the help of a dissection microscope and a sterilized fine point needle. The fungi obtained were preserved in silica-gel according to Dhingra and Sinclair (1996).

Microscope slides were mounted using lactophenol or lactofuchsin. The slides with the fungal structures were examined with a light microscope (Olympus BX 50) equipped with differential interferential contrast (DIC). The line drawings were prepared with the help of a drawing tube fitted to the same microscope.

In order to test the pathogenicity of a newly described species of *Veronaea*, the fungus was grown for ten days in Petri dishes containing 15 mL of VBA medium at 25 ± 2°C and under a 12 hours daily light regime. After this period, inoculation of *Veronaea* was performed both with culture plugs taken from the margins of growing cultures and with triturated mycelium suspended in sterile tap water that was brush-inoculated on both side of healthy leaves. Half of the inoculated portions of tissues were previously wounded by slightly rubbing the leaf surface with sandpaper. The plants were then kept in a dew chamber for 24 hours and then transferred to a shade house and observed daily for symptom development. The same procedure was adopted to *Curvularia lunata* var. *aeria*, except that, for the brush-inoculation, a conidial suspension with 5×10^5 conidia/mL was used instead of the triturated mycelium.

Results

In most areas surveyed, where *Hedychium coronarium* occurred, the populations appeared healthy without any apparent insect or disease damage. Although the worst problems of the invasion of *H. coronarium*

appear to be concentrated in the states of Paraná, São Paulo, Rio de Janeiro and Minas Gerais, some small population were also seen in the states of Goiás, Mato Grosso and Rondônia. These may represent new invasion fronts for the weed or perhaps may be occurrences naturally limited by ecological constraints. Otherwise it is notable that this weed was found more than 3,000 kilometres away from the coast, where presumably the invasion began.

The fungi collected in these surveys are illustrated and described below.

Gonatophragmium mori (Sawada) Deighton, Mycological Paper 117: 13 (1969). (Fig. 1)

Lesions amphigenous, initially as small spots, with a yellow margin, becoming large, pale brown more or less zonate, circular, elliptic to irregular, sometimes coalescing and leading to extensive necrosis of individual leaves; *colonies* mainly hypophyllous, irregularly distributed but more or less zonate. *Primary mycelium* internal, inconspicuous. *Secondary mycelium* superficial, branched, 2-4 µm diam, septate, hyaline, smooth. *Conidiophores* mainly hypogenous, mononematous, macronematous, branched or unbranched, up to 400 µm, 3.5-5 µm diam., septate, smooth, brown, pale toward the apex. *Conidiogenous cells* integrated, terminal or intercalary, mostly laterally nodose, pale brown to subhyaline, smooth or somewhat minutely verruculose, denticulate, denticles distinctly cicatrized, scars somewhat thickened and refractive, 1 µm wide. *Conidia* single, straight to curved, subcylindrical clavate 12.5-24 × 4-5 µm, 1-4 septate, mostly 3-septate, smooth, subhyaline to pale brown or pale olivaceous, median cells slightly darker, apex obtuse, base subacute to denticulate, hila somewhat thickened and refractive. *Germi-nation* lateral, mainly at the basal cell, without formation of appressoria.

Teleomorph: *Acrospermum viticola* Ikata

Material examined: BRAZIL, Rio de Janeiro, Nova Friburgo, Altos dos Michéis, at river margin of Fazenda Barreto, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 3 April 1999, RW Barreto (VIC 30404).

Notes: Only four species of *Gonatophragmium* are presently known. A key to these species based in published information is provided:

1. Conidia consistently wider than 5 µm..... ..... ***G. mangiferae***
1'. Conidia less than 5 µm wide..... 2

2. Conidiophores less than 100 µm long..... .....***G. obscurum***
2'. Conidiophores variable, usually more than 100 µm long..... 3

3. Conidia brown, 2.5-4 µm wide, with a thickened and dark scar ..... ***G. kuanense***
3'. Conidia pale brown, (3.5-) 4-5 (-6) wide, with an unthickened or slight thickened scar ..... ***G. mori***

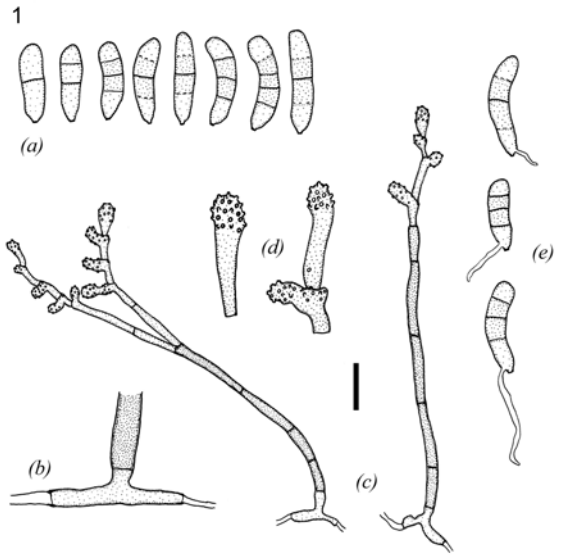


Fig. 1. Line drawings of *Gonatophargium mori* from *Hedychium coronarium*. **a.** Conidia. **b.** Detail of the conidiophore base. **c.** Conidiophores. **d.** Detail of the conidiogenic cells. **e.** Conidial germination. Bar = 10 µm.

Gonatophragmium mangiferae J.L. Mulder has only been recorded on *Mangifera indica* L. in Burma (Mulder, 1973), *G. kuanense* on *Miliusa tomentosa* (Roxb.) J. Sinclair in India (Rai, 1996), and *G. obscurum* on *Psidium guajava* L. from New Zealand (Braun and Hill, 2002). Conversely, *G. mori*, which was originally described on *Morus alba* L. (as *Spondylocladium mori*) from Taiwan, was later recorded on a wide range of hosts (Cejp and Deighton, 1969). According to Ellis (1971) it is often found on *Ficus* in the tropics causing large zonate leaf spots. The morphology of the specimen from *Hedychium*

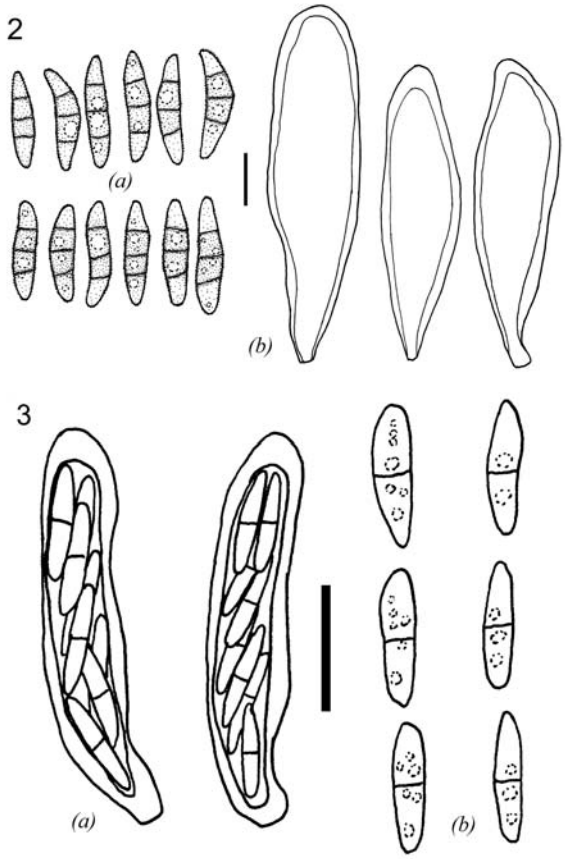
coronarium is similar to that described for *Gonatophragmium mori*, but until now this fungus was not recorded in association with any member of the *Zingiberaceae*.

Leptosphaeria sp. (Fig. 2)

Lesions on living leaves, irregular, amphigenous, pale brown to straw colored. *Internal mycelium* inconspicuous. *External mycelium* absent. *Pseudothecia*, epigenous, immersed, single, globose, 95-140 × 70-110 µm, walls 3-6 layered composed of brown *textura angularis*, 5-12 µm thick, ostiole 4-6 µm diam. *Pseudoparaphyses* filiform, 2-4 µm diam., septate, branched, hyaline. *Asci* bitunicate, fasciculate, clavate to sub-cylindrical, short stalked, 30-70 × 9.5-15 µm, eight spored. *Ascospores* biseriate, fusoid, 3-septate, not constricted at the septa, subapical cell sometimes slightly swollen, 16-20 × 3.5-4.5, guttulate, pale brown to yellowish-brown, slightly verruculose.

Material examined: BRAZIL, Rio Grande do Sul, Bento Gonçalves, road to the Vale dos Vinhedos, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 23 April 2005, DJ Soares (VIC 30405); BRAZIL, Rio Grande do Sul, Planalto, road between Passo Fundo and Planalto, on leaves of *Hedychium coronarium* (*Zingiberaceae*) 25 April 2005, DJ Soares (VIC 30406).

Notes: There are, apparently, only two species of *Leptosphaeria* known in association with the *Zingiberaceae* (Bussaban *et al*., 2002), *L. alpiniae* Maubl. on leaves of *Alpinia nutans* (L.) Roscoe from Brazil (Saccardo, 1913) and *L. zingiberis* (Sawada) V. Dhar, L.S. Srivast. & Sahambi on leaves of *Zingiber officinale* Roscoe from India (Dhar *et al*., 1981). These two species have a very similar morphology. While *L. alpiniae* has asci cylindrical-clavate, 50 × 8-10 µm and ascospores 3-septate, pale brown with 18 × 4-5 µm, *L. zingiberis* has asci fusiform, cylindrical, 45.5-52.5 × 10.5-12.25 µm and ascospores fusiform, mostly 3-septate, light brown with 17.5-22.75 × 3.5-5.25 µm. The specimen on *H. coronarium* from Brazil is also similar to both the *Leptosphaeria* spp., however the presence of guttules and the minutely verruculose walls, in the ascospores, was recorded only in this latter specimen. An undetermined *Leptosphaeria* was previously recorded on *H. coronarium* from Venezuela (Urtiaga, 2004) but unfortunately descriptions were not provided nor specimens cited in this publication. We preferred not to attempt a more precise identification or propose a new name for the *Leptosphaeria* on *H. coronarium* until re-examination of the type specimens of *L. alpiniae* and *L. zingiberis* becomes possible. An additional reason for leaving a more precise treatment for this fungus to be performed at a later occasion is the fact that *Leptosphaeria* is a very large genus, with more than 1500 published names, but according to Kirk *et al*. (2001) *Leptosphaeria* comprehends about 100 species. Many names were proposed based on a supposed restricted host range that remains untested. There are doubts as to the real distinction between some of these species and it is possible that some are conspecific. Apparently, there are species that have a narrow host range and others that are ubiquitous and non-specific (Dennis, 1978; Sivanesan, 1983).



Figs. 2-3. 2. Line drawings of *Leptosphaeria* sp. from *Hedychium coronarium*. **a.** Ascospores showing the minutely verruculose walls and guttules. **b.** Asci. Bar = 10 µm. **3.** Line drawings of *Mycosphaerella hedychii* from *Hedychium coronarium*. **a.** Asci with immature ascopores. **b.** Mature ascopores. Bar = 10 µm.

Mycosphaerella hedychii F. Stevens & P.A. Young, Bernice Bishop Mus. Bull. 19: 103 (1925). (Fig. 3)

Lesions on living leaves, amphigenous, irregular, with a yellowish margin, straw to pale brown. *Pseudothecia* epiphyllous subepidermial, single, globose, 40-75 × 50-70 µm, walls 3-7 layered of brown *textura angularis* cells, 4-10 µm thick; *ostiole* 4-7.5 µm diam. *Asci* bitunicate, fasciculate, cylindrical to cylindrical-clavate, 30-35 × 5-8 µm, eight spored. *Ascospores* biseriate, straight, subcylindrical to fusiform, 8-12 × 2-3.5 µm, 1-septate, not constricted at the septum, hyaline, guttulate, smooth.

Material examined: BRAZIL, Rio de Janeiro, Nova Friburgo, at roadside near the Camping Club do Brasil, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 13 February 2002, RW Barreto, (VIC 30408); BRAZIL, Rio de Janeiro, Itatiaia, Parque Nacional de Itatiaia, near the Hotel Simon, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 28 January 2006, DJ Soares (VIC 30407).

Notes: *Mycosphaerella hedychii* was previously recorded on *H. coronarium* in Hawaii. The fungus on *H. coronarium* from Brazil fits well within the protologue. The size of asci (25-35 × 5-8 µm) and ascospores (8-11 × 2 µm) given in Saccardo (1972) match very closely with the specimen here described. Although the diameter of the ascospores in the material from Brazil is somewhat larger, this difference is not regarded here as sufficient for recognition of a new taxon.

There is a record of *Mycosphaerella* sp. on *H. coronarium* from Venezuela (Urtiaga, 1984) but there was no description or material deposited in a herbarium. It is likely that the *Mycosphaerella* sp. on *H. coronarium* from Venezuela is also *M. hedychii*. Five other species of *Mycosphaerella* are known from members of the *Zingiberaceae*. All are from the Far East (China, Japan and Korea) (Farr *et al*. 2007) and none is associated with *Hedychium* spp.

Pseudocercospora hedychii (Boedijn) U. Braun, Nova Hedwigia 73: 424 (2001). (Fig. 4)

Lesions on living leaves elliptic to irregular, amphigenous, straw colored with a thin brown edge. *Primary mycelium* internal, indistinct. *Secondary mycelium*, superficial, septate, branched poorly-developed, emerging through stomata, mainly as a prolongation of the conidiophores, sub-hyaline to pale olivaceous-brown, 2-4 µm diam. *Stroma* absent or restricted to the stomatal chamber, 10-40 × 15-60 µm, pale to mid brown. *Conidiophores* amphigenous, mainly epiphyllous arising through stomata, initially loosely arranged, becoming densely grouped, also arising from creeping hyphae, straight or slightly curved, 5-60 × 3-4 µm, 0-3 septate, mostly reduced to conidiogenous cells or 1-septate near the base, 1-4 geniculate, pale brown, smooth. *Conidiogenous loci* inconspicuous, unthickened. *Conidia* subcylindrical, 15-80 × 2-4 µm, 1-6 septate, subhyaline to very pale brown, smooth, base truncate to obconically truncate, 2-3.5 diam., apex obtuse to sub-obtuse. *Hila* unthickened not darkened.

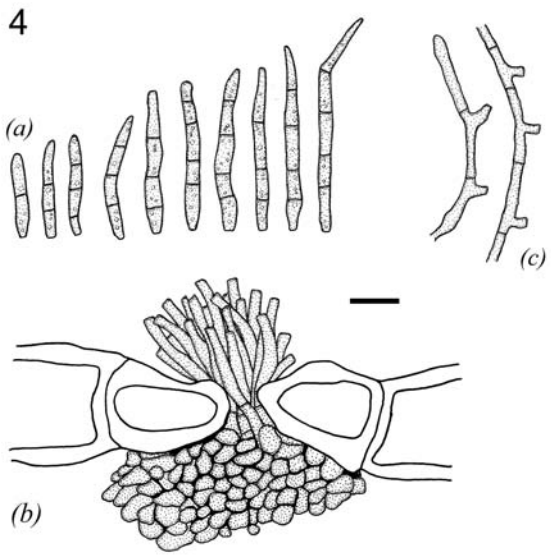


Fig. 4. Line drawings of *Pseudocercospora hedychii* from *Hedychium coronarium*. **a.** Conidia. **b.** Conidiophores rising through a substomatal stroma. **c.** Superficial hyphae with short conidiogenic cells. Bar = 10 µm.

Colonies on MEA compact, raised, compressing the medium at the edges, slow growing (1.5-2 cm diam. after 10 days), velvety, smoke grey, without sporulation, reverse olivaceous black. On OA less compact, more elevated at center, not compressing the medium, cottony, slow growing (2-3.5 cm

diam. after 10 days), colour similar to that on MEA.

Material examined: BRAZIL, Rio de Janeiro, Nova Friburgo, Mury, near waterfall of the Rio Bengala, on leaves of *Hedychium coronarium* (*Zingiberaceae*) 5 April 2000, RW Barreto (VIC 30410); BRAZIL, Minas Gerais, Viçosa, Campus of the Universidade Federal de Viçosa, courtyard of the Biology Building, 25 October 2005, DJ Soares (VIC 30409).

Notes: Only two species of *Pseudocercospora* have been described on the host genus *Hedychium*; *Pseudocercospora costina* (Syd. & P. Syd.) Deighton and *P. hedychii*. Braun (2001a) examined the specimen of *P. costina* on *Hedychium*, and concluded that 'the present material consists of some leaf fragments, so that the correct identification of the host could not be proven'. *Pseudocercospora costina* is known from India, the Philippines and Taiwan on *Costus speciosus*, and is easily distinguished from the specimen from Brazil by the conidiophores and conidial sizes (Deighton, 1976). The description of *P. hedychii* is very similar to the material from Brazil, but it has conidiophores and conidia that are slightly thinner (conidiophores and conidia 2-3 µm wide) than the specimens from Brazil (conidiophores 3-4 µm and conidia 2-4 µm wide). These small biometric differences are regarded as taxonomically insignificant.

Although *M. hedychii* and *P. hedychii* occurred on the same host and *Pseudocercospora* is a common anamorph for *Mycosphaerella* the connection between these two forms was not obvious from field observations (the two fungal forms never being collected together) and although possible, this connection remains to be proven.

Veronaea hedychii D.J. Soares & R.W. Barreto, **sp. nov.** (Fig. 5)
MycoBank: 511024

Etymology: from the host genus *Hedychium*

Differt a *V. botryosa conidiophoris* minoribus 19.5-86.5 × 2.5-3.5 µm, *conidiis* 5-10 × 2-4 µm et *V. constricta conidiis* non constrictus.

Lesions on living leaves initially as small, circular to elliptic spots, 0.2-1 cm diam., becoming confluent causing a blight symptom, straw to pale brown surrounded by an inner brown and an outer yellowish margin. *Internal mycelium* inconspicuous. *External mycelium* hyaline, branched, septate, 1-2.5 µm diam. *Conidiophores* mainly hypophyllous, sometimes epiphyllous, macronematous, mononematous, 19.5-86.5 × 2.5-3.5 µm, sometimes with an inflated base up to 7 µm diam., straight to slightly curved, unbranched, golden brown to brown, paler towards the apices, 1-6 septate, smooth. *Conidiogenous cells* terminal, sometimes intercalary, 10-40 × 1.5-2.5 µm, densely and minute cicatrized, scars thickened, 1 µm wide. *Conidia* holoblastic, dry, 5-10 × 2-4 µm, ellipsoid, cylindrical or obovoid, base obconic truncate, apex rounded, 0-1 septate, sometimes slightly constricted at the septum, subhyaline to pale brown, smooth, hila thickened, somewhat darkened, 1 µm diam.

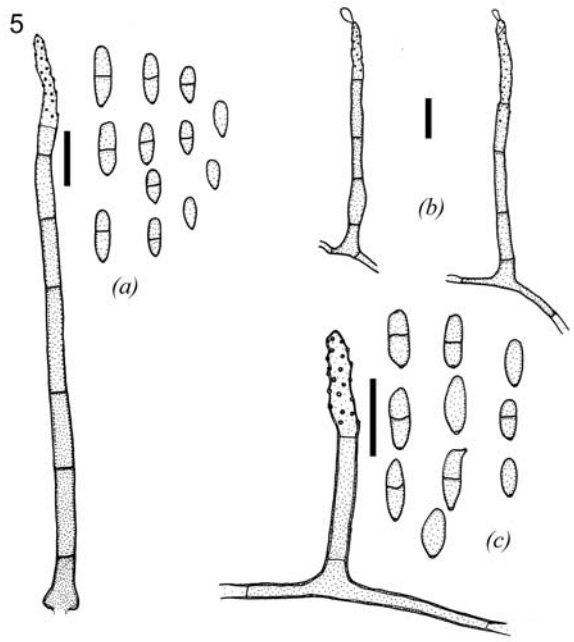


Fig. 5. Line drawings of *Veronaea hedychii* from *Hedychium coronarium*. **a.** Conidiophore and conidia ex holotype. **b.** Conidiophores from culture on VBA medium. **c.** Conidiophore and conidia from slide culture on VBA medium. Bars = 10 µm.

Morphology in slide culture mounts: *Mycelium* pale brown to chestnut brown. *Conidiophores* single, cylindrical, straight, sometimes branched, 20-80 × 2-4 µm, chestnut brown to brown, thick walled, paler and thinner walled towards the apex, smooth. *Conidia* obovoid to subcylindrical, 4-12 × 2.5-3 µm, 0-1 septate, sub-hyaline to pale brown, smooth, often bearing 1-5 secondary conidia, limoniforms, 2-5 × 1-3 µm, aseptate, smooth.

Colonies on VBA brown to chestnut brown, flat, slow growing, (2 cm diam. after 10

days), sporulating abundantly, reverse brown to dark brown; on PDA aerial mycelium well developed, woolly, raised at centre, grey olivaceous, slow growing, (2-2.5 cm diam. after 10 days), sporulating poorly, reverse olivaceous black; on MEA compact, aerial mycelium well developed, woolly, slow growing (2-2.2 cm diam. after 10 days), grey olivaceous, without sporulation, reverse olivaceous black; on OA poorly developed, with scattered aerial mycelium, slow-growing (2.5 cm diam. after 10 days), grey olivaceous, reverse dark-grey.

Teleomorph: not seen.

Habitat: On living leaves of *Hedychium coronarium*.

Known distribution: São Paulo, Minas Gerais, Rio de Janeiro and Paraná states of Brazil.

Material examined: BRAZIL, São Paulo, road SP 165, Km 162, 24º 32' 28" S / 48º 42' 47" W, on leaves of *Hedychium coronarium* (*Zingiberaceae*), June 2006, DJ Soares (VIC 30419 - **holotype**); BRAZIL, São Paulo, road between Jacupiranga and Eldorado, 24º 40' 55" S / 40º 00' 41" W, 17 May 2005, DJ Soares (VIC 30411); BRAZIL, São Paulo, road between Iporanga and Barra do Turvo, 17 May 2005, DJ Soares (VIC 30412); BRAZIL, São Paulo, road between Iporanga and Barra do Turvo, 17 May 2005, DJ Soares (VIC 30413); BRAZIL, São Paulo, road between Iporanga and Barra do Turvo, 17 May 2005, DJ Soares (VIC 30414); BRAZIL, Minas Gerais, road near Rosário da Limeira, October 2005, DJ Soares (VIC 30415); BRAZIL, Rio de Janeiro, Nova Friburgo, Macaé de Cima, road to Ouro Verde Farm, October 2005, DJ Soares (VIC 30416); BRAZIL, Minas Gerais, road BR 267, near the entrance of Liberdade, 18 November 2005, DJ Soares (VIC 30417); BRAZIL, Paraná, Almirante Tamandaré, Clube Atlético Primavera, 20 November 2005, DJ Soares (VIC 30418); BRAZIL, Rio de Janeiro, Itatiaia, Parque Nacional de Itatiaia, near Hotel Simon, 28 January 2006, DJ Soares (VIC 30407); BRAZIL, Rio de Janeiro, Nova Friburgo, roadside near the Camping Club do Brasil, 13 February 2002, RW Barreto, (VIC 30408); BRAZIL, Rio de Janeiro, Nova Friburgo, Macaé de Cima, 17 May 2002, RW Barreto (VIC 30420); BRAZIL, Rio de Janeiro, road between Rio de Janeiro and Teresópolis, 15 April 2003, RW Barreto (VIC 30421).

Notes: Twenty four species have been described in the genus *Veronaea* Cif. & Montemart. Four have been transferred to *Ramichloridium* Stahel ex de Hoog [*R. apiculatum* (J.H. Mill., Giddens & A.A. Foster) de Hoog, *R. ellipticum* (A.D. Sharma & Munjal) de Hoog, *R. anceps* (Sacc. & Ellis) de Hoog, & *R. verrucosum* (Geeson) B. Sutton], and one was transferred to *Stenella* Syd. (*S. gorakhpurensis* (Kamal & P. Kumar) de Hoog.]. Although de Hoog (1977) and de Hoog *et al*. (1983) proposed that several other species of *Veronaea* should be the transferred to *Ramichloridium* such recombinations were not made. *Ramichloridium* and *Veronaea* are somewhat hard to distinguish, but whereas *Veronaea* has cicatrized, usually small flat pigmented conidial scars and conidia that are usually two-celled, *Ramichloridium* has either an apical denticulate rhachis or scattered conidium-bearing denticles, with conspicuous unpigmented or slightly pigmented scars, and conidia that are one-celled, rarely 2-(4-)-celled (de Hoog, 1977).

Among the 18 accepted species of *Veronaea*, nine are considered saprobes [*V. bambusae* Morgan-Jones; *V. botryosa* Cif. & Montemart.; *V. caricis* M.B. Ellis; *V. carlinae* M.B. Ellis; *V. compacta* Papendorf; *V. constricta* Moustafa & Abdul-Wahid; *V. indica* (Subram.) M.B. Ellis; *V. queenslandica* Matsush.; and *V. simplex* Papendorf], two are mycoparasites [*V. filicina* Dingley; and *V. harunganae* (Hansf.) M.B. Ellis], one is a nematode pathogen (*V. oblongispora* Morgan-Jones) and six are plant pathogens (*V. ficina* Kharwar & R.K. Singh; *V. grewiicola* Kharwar & R.K. Singh; *V. hippocratiae* Kharwar & R.K. Singh; *V. musae* M.B. Ellis; *V. smilacis* R.P. Singh, Kamal & Abassi; and *V. tectonae* Kamal & P. Kumar). Only seven of these species are currently thought to belong in *Veronaea* (*V. bambusae*; *V. caricis*; *V. carlinae*; *V. compacta*; *V. constricta*; *V. musae*; and *V. simplex*). According to de Hoog *et al*. (1983) *V. tectonae* and *V. smilacis* also belong to *Stenella* and *V. smilacis* is probably identical to *S. smilacis* P. Kumar, D.N. Shukla & Kamal (Kumar *et al*. 1980). Apparently de Hoog's view is correct since *S. smilacis* and *V. smilacis* are recorded from the same host and locality and the descriptions are very similar (Kumar *et al*. 1980; Singh *et al*. 1981). Similarly to de Hoog's view (de Hoog *et al*. 1983) it is likely that *V. ficina*, *V. grewiicola* and *V. hippocratiae*, which were recently described (Kharwar and Singh, 2004) would be better

placed in *Stenella* since they have superficial colonies, one-septate to pluriseptate conidia that are, pale brown and slightly verruculose. Nevertheless, such a name change would require a carefull re-examination of the types. *Veronaea hedychii* is very close to *V. constricta* and *V. botryosa* but differs from *V. constricta* mainly by having conidia that are not distinctly constricted at the septae and which are sometimes aseptate. It differs from *V. botryosa* by having conidia that are not more than 1-septate and conidiophores that are smaller than those of *V. botryosa* which reach up to 400 µm. Although *V. botryosa* is predominantly 1-septate, conidia with more than one septum are frequently found. Additionally *V. botryosa* is not known to occur as a plant pathogen, as shown for *V. hedychii*, and has been reported either as a saprobe or as a rare agent of human phaeohyphomycosis (Sutton *et al*. 2004; Matsushita *et al*. 2003) and *V. constricta* is a fungus that has been only isolated from soil. The pathogenicity test resulted in disease only on wounded leaves 4 days after the inoculation. After fourteen days the wounded inoculated leaves were completely blighted and examination of damaged tissues under stereomicroscope revealed abundant sporulation of *V. hedychii*. The fungus was than re-isolated from fragments of infected tissues. No symptoms were observed in the non-wounded inoculated leaves, even after 30 days of the inoculation, demonstrating its opportunistic wound pathogen status (Fig. 6).

Curvularia lunata* var. *aeria (Bat., J.A. Lima & C.T. Vasconc.) M.B. Ellis, Mycological Paper 106: 34 (1996).

For synonyms, illustrations, descriptions and substrates see: Sivanesan (1987) and Ellis (1966, 1971).

Material examined: BRAZIL, Rio Grande do Sul, Bento Gonçalves, road to the Vale dos Vinhedos, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 23 April 2005, DJ Soares (VIC 30405).

Notes: This fungus was found only once on a few leaves associated with pre-existing injuries of an undetermined cause. It was isolated and the morphology of conidia, conidiophores and cultural characteristics, including the presence of digitate stromata, was recognized as being very close to that of *C. lunata* var. *aeria*. This fungus is known to be a plurivorous saprobe or plant pathogen mainly in graminicolous hosts and other monocotyledonous hosts (Ellis, 1971; Sivanesan, 1987). No symptoms were observed after the inoculation of this fungus on leaves of *H. coronarium*, according to the methodology previously described. *C. lunata* var. *lunata* was already recorded on members of the family *Zingiberaceae*, but apparently this is the first record of *C. lunata* var. *aeria* having one member of this family as its substrate.

Chalara aurea (Corda) S. Hughes, Can. J. Bot. 36: 747 (1958).

Material examined: BRAZIL, Goiás, Serranópolis, Pousada das Araras, Caminho Olho D' Água, on leaves of *Hedychium coronarium* (*Zingiberaceae*), 23 May 2006, DJ Soares (VIC 30427).

For descriptions and illustrations see: Nag Raj and Kendrick (1975).

Notes: This fungus was found only once growing on leaves of *H. coronarium* consistently associated with elliptic to irregular pale brown spots, however the pathogenicity cannot be proven because we were unable to isolate the fungus. The general morphology of the fungus found on *Hedychium* is very close to that of *Ch. aurea*. This fungus is well known from UK and Austria (Nag Raj and Kendrick, 1975) associated with wood chips, bark and dead branches of *Aesculus*, *Betula*, *Carpinus Ilex* and *Quercus*. Recently (Piccolo Grandi and Silva Attili, 1996) recorded this fungus on leaf litter of *Alchornea triplinervia* (Spreng.) Müll. Arg. from Brazil. However this is the first record of this species in association with living leaves of *H. coronarium*. Its ecological interaction with *H. coronarium* remains obscure at this stage, but it seems to be an opportunist pathogen.

Discussion

All the fungal records presented in this work represent either new hosts or new geographic records for each fungus. The record of *G. mori* is considered here as a new host-pathogen association. The geographic distribution of *Leptosphaeria* sp. on *Hedychium*, *M. hedychii* and *P. hedychii* were expanded here to include Brazil. *C. lunata* var. *aeria*, here considered non-pathogenic, and *Chalara aurea*

Fig. 6. Result of the pathogenicity test of *Veronaea hedychii*, 30 days after the inoculation, showing the wounded and un-inoculated leaf without progress of the lesion **a,** and the leaves curling and complete necrosis of the inoculated leaf **b.**

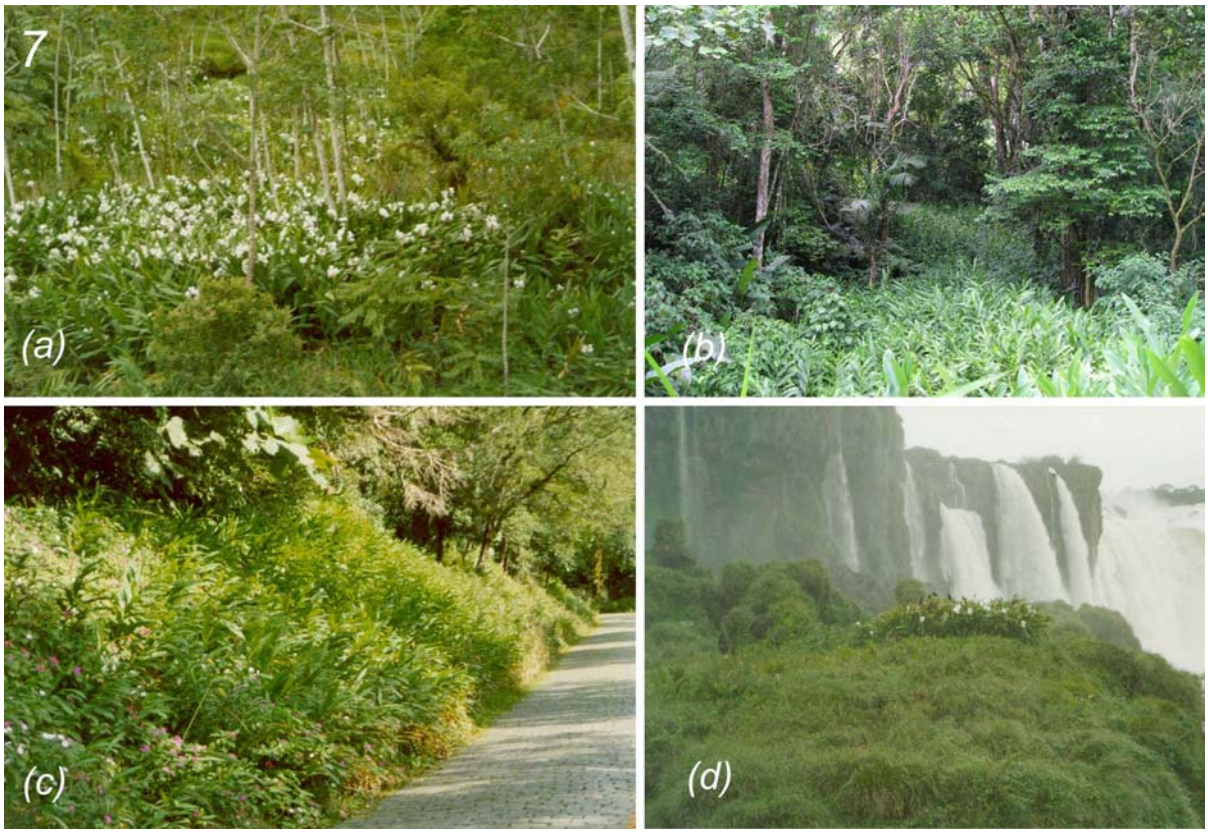


Fig. 7. Biological invasion of *Hedychium coronarium* in protected areas of Brazil. **a.** Invasion of a wetland plain in the Estação Ecológica do Tripuí, Ouro Preto, MG. **b.** Understory invasion near the Caverna do Diabo, Barra do Turvo, SP. **c.** Understory invasion at roadside of the Graciosa Road, a protected area of Atlantic rain forest in the state of Paraná. **d.** Early stages of the invasion of the Iguaçu Waterfalls area in the state of Paraná.

appearing to be a weak opportunist pathogen, are recorded having *H. coronarium* as a new substrate. For the latter this also represents a new geographic record. The sole taxonomic novelty resulting from this work is *V. hedychii* and although the genus *Veronaea* is better known as having a saprobe habit, the pathogenic status of *V. hedychii* was demonstrated herein.

None of these fungi emerge from the field observations or literature records as of particular interest for biological control. In the

cases of *M. hedychii* and *P. hedychii* the growth in culture is very slow and they did not sporulate. Additionally the damage caused by these two fungi is not particularly significant, therefore they do not appear promising for mycoherbicide development. *Gonatophragmium mori*, although capable of producing large lesions and significant damage to individual leaves, caused lesions in only few leaves per plant, even in very dense stands of *H. coronarium*. It is also known to have a wide host range and, therefore, it does not appear to be useful for biological control. *Leptosphaeria* sp. has an uncertain identity and host range and, *V. hedychii* needs wounding of *H. coronarium* in order to infect it, however a more accurate analysis of its specificity and aggressiveness could be further investigated.

The problem of *H. coronarium* in Brazil and other parts of the world where it is producing unchallenged monotypic stands typical of a biological invasion (Fig. 7) is likely to be potentially solved by classical biological control (El-Morsy *et al*., 2006; Pereira and Barreto, 2006; Pereira *et al*. 2007) with arthropod or pathogen natural enemies or a combination of agents obtained from the centre of origin of the plant. It is of great concern that as awareness of the relevance of the problem with white ginger, as well as the other wild gingers, is on the rise, the humid submontate forest ecosystems where it was originally confined at the Eastern Himalayas (Herb. K records) are listed as among the most threatened ecosystems in the world and wild gingers are listed as endangered in their native ranges, e.g.: *H. gardnerianum* var *stenopectatum*, is listed as endangered by the Botanical Survey of India (Anonymous, 2007) as well as *H. coronarium* (Chadha, 2005). Such an ironic situation highlights the need to preserve endangered ecosystems as, additionally to other reasons, the loss of plant species in their native habitats would represent the loss of specialized natural enemies that would represent the best hope for controlling their infestations where they have become invasive in other parts of the world. A multi-party effort at searching natural enemies of wild ginger for use in classical biological control is now being organized with the involvement of scientists and potential funding from Hawaii, the UK, Brazil and New Zealand among others.

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References

Anderson, R.C. (2003). Battling the fragrant invader: mass production, application, and implementation of biological control for kahili ginger (*Hedychium gardnerianum*). Proceedings of the VI International Bioherbicide Workshop. Canberra, Australia.

Anderson, R.C. and Gardner D.E. (1999). An evaluation of the wilt-causing bacterium *Ralstonia solanacearum* as a potential biological control agent for the alien kahili ginger (*Hedychium gardnerianum*) in Hawaii Forests. Biological Control 15: 89-96.

Anonymous (2007). *Eastern Circle*, *Shillong (Botanical Survey of India) - Rare and endangered species*. Retrieved January 5, 2007 from http://164.100.52.111/circles/ Eastern/ RAREANDENDANGEREDSPECIES.shtm.

Asner, G.P. and Vitousek, P.M. (2005). Remote analysis of biological invasions and biogeochemical change. Proceedings of National Academic Science 102: 4383-4386.

Barreto, R.W. (1991). *Studies on the pathogenic mycoflora of selected weeds from the State of Rio de Janeiro (Brazil)*. Ph D. Thesis. University of Reading, England.

Braun, U. (2001a). Taxonomic notes on some species of the *Cercospora* complex (VII). Fungal Diversity 8: 41-71.

Braun, U. (2001b). Revision of *Cercospora* species described by K.B. Boedijn. Nova Hedwigia 73: 419-436.

Braun, U. and Hill, C.F. (2002). Some new micromycetes from New Zealand. Mycological Progress 1: 19-30.

Bussaban, B., Lumyong, P., McKenzie, E.H.C., Hyde, K.D. and Lumyong, S. (2002). Index of fungi described from the Zingiberaceae. Mycotaxon 83: 165-182.

Cejp, K. and Deighton, F.C. (1969). Microfungi III: Some African species of *Phyllostica* and *Septoria*; New genera and species and redispositions of some hyphomycetes, mainly African. Mycological Papers 117: 1-31.

Chadha, S. (2005). Vulnerable and threatened plants of economic value. *Hedychium coronarium* Koering. MFP News 15: 19-20.

de Hoog, G.S. (1977). The black yeast and allied hyphomycetes. Studies in Mycology 15: 1-222.

de Hoog, G.S., Rahman, M.A. and Boekhout, T. (1983). *Ramichloridium*, *Veronaea* and *Stenella*: generic delimitation, new combinations and two new species. Transactions of British Mycological Society 81: 485-490.

Deighton, F.C. (1976). Studies on *Cercospora* and allied genera. VI. *Pseudocercospora* Speg., *Pantospora* Cif. and *Cercoseptoria* Petr. Mycological Papers 140: 1-168.

Dennis, R.W.G. (1978). *British Ascomycetes*. J. Cramer, Vaduz.

Dhar, V., Srivastava, L.S. and Sahambi, H.S. (1981). *Leptosphaeria* leaf spot and blight of ginger in India. Current Science 50: 540.

Dhingra, O.D. and Sinclair, J.B. (1996). *Basic Plant Pathology Methods*. Second Edition, Lewis Publishers, Boca Raton.

Ellis, M.B. (1966). Dematiaceous Hyphomycetes. VII: *Curvularia*, *Brachysporium* etc. Mycological Papers 106: 1-57.

Ellis, M.B. (1971). *Dematiaceous Hyphomycetes*. CMI, Kew, Surrey, England.

Ellis, M.B. (1976). *More Dematiaceous Hyphomycetes*. CMI, Kew, Surrey, England.

Ellison, C.A. and Barreto, R.W. (2004). Prospects for the management of invasive alien weeds using co-evolved fungal pathogens: a Latin American perspective. Biological Invasions 6: 23-45.

El-Morsy, E.M., Dohlod, S.M. and Hyde, K.D. (2006). Diversity of *Alternaria alternata* a common destructive pathogen of *Eichhornia crassipes* in Egypt and its potential use in biological control. Fungal Diversity 23: 139-158.

Farr, D.F., Rossman, A.Y., Palm, M.E. and McCray, E.B. (2007). Fungal databases, systematic botany and mycology laboratory, ARS, USDA. Retrieved November 5, 2006, from http://nt.ars-grin.gov/fungaldatabases/.

Harris, R., Stewart, C. and Syrett, P. (1999). *Wild ginger (Hedychium spp.)*: *Prospects for biological control*. Unpublished Landcare Research Report.

Kharwar, R.N. and Singh, R.K. (2004). Additions to the hyphomycetes genus *Veronaea* as phytoparasitic species. Microbiological Research 159: 103-111.

Kirk, P.M., Cannon, P.F., David, J.C. and Stalpers, J.A. D.N. (2001). *Dictionary of the Fungi*. 9th CABI, Surrey, England.

Kissmann, K.G. (1997). *Plantas infestantes e Nocivas* (Vol. I) 2nd Ed. (BASF Brasileira SA: São Paulo).

Kumar, P., Shukla, D.N. and Kamal (1980). A new species of *Stenella* from India. Current Science 49: 234-235.

Loope, L., Starr, F. and Starr, K. (2004). Protecting endangered plant species from displacement by invasive plant from Maui, Hawaii. Weed Technology 18: 1472-1474.

Mabberley, D.J. (2002). *The plant-book: a portable dictionary of the vascular plants*. 2nd ed. Cambridge University Press. Cambridge, UK.

MacDonald, I.A.W., Thebaud, C., Strahm, W.A. and Strasberg, D. (1991). Effects of alien plant invasions on native vegetation remnants on La Reunion (Mascarene-Islands, Indian-Ocean). Environmental Conservation 18: 51-61.

Macedo, J.F. (1997). O gênero *Hedychium* Koening (Zingiberaceae) no estado de Minas Gerais. Daphne 7: 27-31.

Matsushita, A., Jilong, L., Hiruma, M., Kobayashi, M., Matsumoto, T., Hogawa, H. and Padhye, A.A. (2003). Subcutaneous phaeohyphomycosis caused by *Veronaea botryosa* in the People's Republic of China. Journal of Clinical Microbiology 41: 2219-2222

Mulder, J. (1973). *Gonatophragmium mangiferae* sp. nov. on *Mangifera indica*. Transactions of British Mycological Society 60: 160-162.

Nag Raj, T.R. and Kendrick, B. (1975). *A monograph of Chalara and allied genera*. Wilfrid Laurier University Press, Waterloo, Ontario, Canada.

Pedralli, G., Freitas, V.L.O., Meyer, S.T., Teixeira, M.C.B. and Gonçalves, A.P.S. (1997). Levantamento florístico na Estação Ecológica do Tripuí, Ouro Preto, MG. Acta Botânica Brasílica 11: 191-213.

Pedralli, G. and Meyer, S.T. (1996). Levantamento da vegetação aquática ("macrofitas") das florestas de galeria na área da Usina hidrelétrica Nova Ponte, Minas Gerais. Bios 4: 49-60.

Pereira, J.M., Barreto, R.W., Ellison, C. and Maffia, L.A. (2003). *Corynespora cassicola* f. sp. *lantanae*: a potential biocontrol agent for *Lantana camara* from Brazil. Biological Control 26: 21-31.

Pereira, O.L. and Barreto, R.W. (2006). *Pseudocercospora palicoureae* sp. nov. associated with the toxic rubiaceous weed *Palicourea marcgravii* in Brazil, with observations on its mycobiota. Fungal Diversity 23: 243-253.

Pereira, O.L., Barreto, R.W., Cavallazzi, J.R.P. and Braun, U. (2007). The mycobiota of the cactus weed *Pereskia aculeata* in Brazil, with comments on the life-cycle of *Uromyces pereskiae*. Fungal Diversity 25: 127-140.

PIER– Pacific Island Ecosystems at Risk (2006). *Hedychium coronarium*. Retrieved December 08, 2006, from http://www.hear.org/Pier/species/hedychium_coronarium.htm.

Piccolo Grandi, R.A. and Silva Attili, D. (1996). Hyphomycetes on *Alchornea triplinervia* (Spreng.) Müll. Arg. Leaf litter from the ecological reserve Jureiaitatins, State of São Paulo, Brazil. Mycotaxon 60: 373-386.

Rai, A.N. (1996). A new species of *Gonatophragmium* from the forest flora of the Indian sub-continent. Mycological Research 100: 1263-1264.

Saccardo, P.A. (1913). *Sylloge Fungorum* XXII: 229.

Saccardo, P.A. (1972). *Sylloge Fungorum* XXVI: 342.

Santos, G.L., Kageler, D., Gardner, D.E. and Stone, C.P. (1998). *Herbicidal control of selected alien plant species in Hawaii Volcanoes National park*: *a preliminary study*. Technical Report 60. Cooperative National Park Resources Studies Unit/Univ. of Hawaii at Manoa, Honolulu.

Santos, S.B. (2004). *Aspectos da biologia e fenologia da população de Hedychium coronarium Koening (Zingiberaceae) na Estação Ecológica do Tripuí*, *Ouro Preto*, *MG*. Graduate Monograph. Universidade Federal de Ouro Preto. Brazil.

Santos, S.B., Pedralli, G. and Meyer, S.T. (2005). Aspectos da fenologia e ecologia de *Hedychium coronarium* (Zingiberaceae) na Estação Ecológica do Tripuí, Ouro Preto, MG. Planta Daninha 23: 175-180.

Singh, R.P., Kamal and Abbasi, P. (1981). A new species of *Veronaea*. Current Science 50: 236-238.

Sivanesan, A. (1987). Graminicolous species of *Bipolaris*, *Curvularia*, *Drechslera*, *Exserohilum* and their teleomorphs. Mycological Papers 158: 1-259.

Sivanesan, A. (1984). *The bitunicate ascomycetes and their anamorphs*. J. Cramer, Vaduz.

Strauss, S.Y., Webb, C.O. and Salamin, N. (2006). Exotic taxa less related to native species are more invasive. Proceedings of National Academic Science 103: 5841-5845.

Souza, V.C., Lorenzi, H. (2005). *Botânica Sistemática*: *guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II.* (Editora Platarum: Nova Odessa, São Paulo).

Sutton, D.A., Rinaldi, M.G. and Kielhofner, M. (2004). First US report of subcutaneous phaehyphomycosis caused by *Veronaea botryosa* in a heart transplant recipient and review of the literature. Journal of Clinical Microbiology 42: 2843-2846

Urtiaga, R. (1986). *Indice de enfermedades en plantas de Venezuela y Cuba*. (Publisher by the author: Lara.)

Urtiaga, R. (2004). *Indice de enfermedades y desordenes en plantas de Venezuela - Addendum*. Unknown Publisher.

Williams, P.A., Winks, C. and Rijkase, R. (2003). Forest process in the presence of wild ginger (*Hedychium gardnerianum*). New Zealand Journal of Ecology 27: 45-54.