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Fungal Pathogens of Weeds Collected in the Brazilian Tropics and Subtropics and their Biological Control Potential

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A 2-yr survey of fungal pathogens associated with 30 selected weeds was undertaken in Southern Brazil. The survey was concentrated in 81 sampling sites in the State of Rio de Janeiro but fungi collected in other Brazilian States were also included in this study. The taxonomy and ecology of the most significant fungi were investigated. The extent of damage caused by the fungi to the weeds in field situations, together with the environmental requirements and host range studies of weed-fungal associations, were taken into consideration for estimating their potential use as biological control agents. The following fungi are considered to be promising for weed control utilizing the classical (c) or mycoherbicide (m) approaches: for *Bidens pilosa–Sphaceloma bidentis* (c/m); for *Chromolaena odorata–Mycovellosiella perfoliata* (c), *Anhellia niger* (c), and *Septoria ekmaniana* (c); for *Cyperus rotundus–Dactylaria higginsii* (m), *Duosporium cyperi* (m), *Pucçinia canaliculata* (c); for *Euphorbia heterophylla –Alternaria euphorbiicola* (m); *Bipolaris euphorbiae* (c/m), *Sphaceloma poinsettiae* (c/m) and *Uromyces euphorbiae* (c); for *Lantana camara–Mycovellosiella lantanae* var. *lantanae* (c), *Prospodium tuberculatum* (c), *Puccinia lantanae* (c) and the new species *Septogloeum pustuliformis* (c); for *Mikania micrantha–Puccinia spegazzini* (c) and the new species *Mycosphaerella mikanifolia* (c) and *Basidiophora montana* (c); for *Mimosa invisa–Pseudocercospora* sp. and *Uredo mimosae-invisae* (c); for *Sida acuta–Alternaria* sp. (m) and *Septoria guaximae* (c/m); for *Sida rhombifolia–Mycovellosiella sidae* (c) and *Septoria guaximae* (c/m). The possibility of promoting "new encounters" between fungal pathogens associated with *Imperata brasiliensis* in Brazil with the closely related grassy weed *Imperata cylindrica* in the Old World merits investigation, since none of their pathogens are shared.

Introduction

The tropics are widely regarded by mycologists as having a rich, diversified and little known mycoflora. If Brazil has a similar proportion of the World's mycoflora, as that estimated by Prance (1979) for its higher plant flora (about one-fifth of the world total), then the Brazilian mycoflora would amount to some 300,000 species. The World's total number of fungal species was recently estimated as 1,500,000 species by Hawksworth (1991), who is of the opinion that only 5% of the existing fungi are known to science. Knowledge of the Brazilian mycoflora is probably even more deficient because mycological activity has been limited in relation to the size and diversity of the country. This is particularly true for fungi causing disease of non-crop plants.

The feasibility of utilizing fungal pathogens as biological control agents of weeds has been demonstrated during the last 2 decades, both for the classical and mycoherbicide approaches, and this suggests that, among these neglected tropical and sub-tropical fungi, there may be many weed pathogens that could prove to be beneficial. The cost/benefit analysis of the pioneering project of classical weed biological control utilizing a fungal pathogen, *Puccinia chondrillina*, Bubak & Sydenham (Uredinales), against *Chondrilla juncea* L. (Compositae) in Australia, was recently reviewed and benefits are now estimated at AUS $ 650 million, for an investment of *ca.* AUS $ 3 million (Hasan, S., personal communication, 1991). The developments in this relatively new field are well documented in the literature which has been reviewed recently in TeBeest (1991).

In Brazil, the only attempt to utilize a fungal pathogen as a biological control agent is being undertaken by a research group based at the EMBRAPA/CNPSo, at Londrina (State of Paraná). In this project the potential of a *Helminthosporium*-like fungus is being evaluated for mycoherbicide development against milkweed *Euphorbia heterophylla* L. (Euphorbiaceae) (Yorinori 1985, 1987; Yorinori and Gazzieiro 1989). So far, no attempt has been made to explore the classical approach for weed control in Brazil. Native and exotic fungal pathogens of indigenous or introduced weeds remain, therefore, in Brazil, as in most of the rest of the world, a vast and untapped, sustainable resource.

Many of the serious agricultural and environmental weeds in Brazil are introduced species. Conversely, many plant species native to Brazil, which were introduced into the Old World, have become serious weeds in their new environments. This suggests a potential of great benefit in the controlled interchange of weed pathogens.

In 1987, a research project was initiated, in order to generate information about the weed mycoflora associated with a selected group of native and introduced weeds, present in Brazil. Literature, herbaria and field surveys of the fungal natural enemies of these weeds were undertaken. Such information, together with the selection of suitable target weed species (Schroeder 1983), constitute the preliminary steps in any weed biological control programme, and is intended to be used to stimulate further work in this neglected field in Brazil.

Evans (1987) made a preliminary assessment of the biological control potential of the fungal pathogens of 18 important subtropical and tropical weeds. This work was based on information from the literature and on examination of herbarium material deposited at the International Mycological Institute (IMI, formerly the Commonwealth Mycological Institute). These observations, together with information on the distribution of the host-pathogen associations, resulted in a source of information for those interested in weed biological control, particularly in the tropics. The present work covers most of the weeds discussed by Evans (1987) plus several additional weed species. The target weeds species are listed in Tables 1 and 2. Detailed information about these weeds are given in Holm *et al.* (1987), Holm *et al.* (1979) and Lorenzi (1991).

This is the first systematic survey undertaken in Brazil with the specific aim of finding fungal pathogens of weeds with biological control potential. A summary of the preliminary results is presented here.

Methodology

The sampling programme was concentrated in the State of Rio de Janeiro, which is a relatively small (43 305 sq. km) Brazilian state. This state has a well diversified topography including coastal plains and mountainous regions, up to 2,787 m.a.s.l., and a good range of climatic zones, varying from tropical to subtropical, are represented. Climatic data obtained from meteorological stations (44 yrs data, Anonymous 1978) were used, firstly to aid the selection of representative sampling sites and later as circumstantial evidence of environmental preferences for fungal-host associations. Eleven aquatic sites and 70 terrestrial sites were chosen, the former including major freshwater aquatic ecosystems (lakes, lagoons, reservoirs or rivers), the latter comprising crop, pasture or ruderal sites. These sites were visited 2 or 3 times over a period of 11 months (from October 1988 to August 1989). Each terrestrial site had an area of 5,000-10,000

Table 1. Fungal pathogens of selected weeds–summary of data.

Fungi	Taxo-onomy	Prev. Recs.	Occ. Rio	Climate Temp.	Climate Precip.	Seas.	Org.	Dis.	Dam.	Culture Grow.	Culture Spor.	Potential Clas.	Potential Mycoh.
HOST: *Chromolaena odorata* (L.) King & Robinson (Compositae)				17.5-24	800-2200								
Alternaria zinniae M.B. Ellis	s	0	+	23-24	1000-2000	su,wi	l	n	++	f	++	+	++
Anhellia niger (Viegas) von Arx	s	0	+	20-23	1200-1300	wi	all	n,s	+++	s	+++	++	+
Fusarium pallidoroseum (Cooke) Saccardo	s	0	+	23	1200	su,au	s	c	+++*	f	+++	–	–
Mycovellosiella perfoliata (Ellis & Everhart) Muntañola	s	0	*	–	–	wi	l	n	++	s	+++	++	++
Ophiociliomyces bauhiniae A.C. Batista & H. Lima	s	0	+++	17.5-24	800-2200	all	all	so	+	0	–	0	0
Pseudocercospora eupatorii-formosanii (Sawada) Yen	s	As,Oc	+	17.5-23.5	1000-2000	all	l	n	++	s	0	0	0
Redbia trichomambustus R.W. Barreto	ns	0	++	17.5-23.5	800-2000	au,wi,sp	l	n	+	s	0	0	0
Septoria ekmaniana Petrak & Ciferri	s	Do,Br	++	17.5-23.5	800-2200	all	l	n	++	–	–	++	–
HOST: *Cyperus rotundus* L. (Cyperaceae)				17.5-24	800-2200								
Cercospora caricis Oudemans	s	Au,Af	+	17.5-23.5	800-1400	all	l	n	++	s	0	0	0
Cintractia limitata Clinton	s	C	+	23.5	1200	au	i	sm	+	–	–	0	–
Dactylaria higginsii (Lutrell) M.B. Ellis	s	C	+	22.5-23.5	1200-2200	all	l	n	++	s	+++	0	++
Duosporium cyperii Thind & Rawla	s	0	+	22-23.5	1100-2200	all	l	n	+++	s	+++	+	++
Puccinia canaliculata (Schweinitz) Lagerheim	e	*	+	22.5-23.5	1100-1300	all	l	r	++	0	0	*	a
HOST: *Echinochloa polystacha* (H.B.K.) Hitchcock (Gramineae)				20.5-23.5	1100-1300								
Phaeoramularia acroinflata R.W. Barreto	ms	0	++	20.5-23.5	1100-1200	all	l	n	+	s	+	+	+
Phoma sp.	u	0	+	20.5	1200	su	l	n	+	–	–	–	–
Uredo wrmicoides Spegazzini	u	Ar	++	20.5-22	1200-1300	all	l	r	+	0	0	+	a

Table 1. Continued.

Fungi	Taxo-onomy	Prev. Recs.	Occ. Rio	Climate		Seas.	Org.	Dis.	Dam.	Culture		Potential	
				Temp.	Precip.					Grow.	Spor.	Clas.	Mycoh.
HOST: *Eichhornia azurea* (Swartz) Kunth (Pontederiaceae)				20.5-23.5	1100-1300								
Acremonium sp.	u	0	+	23.5	1100	sp	l	n	*	–	–	–	–
Cercosporella pontederiae (Ellis & Dearness) J.J. Davis	s	0	+++	20.5-23.5	1100-1300	all	l	n	++	s	+	–	++
Pyricularia griseae Saccardo	s	0	+++	20.5-23.5	1100-1300	all	l	ts	++	s	0	–	++
Uromyces pontederiae Gerad	s	Ur	++	20.5-23.5	1200	all	l	r	++	0	0	–	a
HOST: *Eichhornia crassipes* (Martius) Solms-Laubach (Pontedericaeae)				20.5-23.5	1100-1300								
Cercospora piaropii Tharp	s	As,Am	++	22-23.5	1100-1200	all	l	n	+	s	++	+	++*
HOST: *Euphorbia heterophylla* L. (Euphorbiaceae)				17.5-24	800-2200								
Alternaria euphorbiicola Simmons & Englehard	s	Eg	++	20.5-24	1100-1800	au,wi,sp	l,s	n	++	f	++	+	++
Bipolaris euphorbiae (Hansford) Muchovej	s	S Br	++	22-23.5	1100-1300	all	l,s	n	+++	f	+++	++	+
Botrytis ricini Buchwald	s	Br	++	17.5-24	1200-1800	all	l	n	++	s	+	0	+
Oidium sp.	u	C	+	22.5	1200	wi	l	pm	+	0	0	0	0
Sphaceloma poinsettiae Jenkins	s	Br,Cu	++	17.5-24	1100-1400	all	l,s	s	+++	s	+++	++	++
Uredo sp. (*Melampsora* sp.?)	u	–	+	20.5	1300	wi	l	r	++	0	0	–	a
Uromyces euphorbiae Cooke & Peck	s	Am	++	17.5-24	800-2200	all	l	r	++	0	0	++	a
HOST: *Euphorbia hirta* L. (Euphorbiaceae)				17.5-24	800-2200								
Botrytis ricini Buchwald	s	0	+	24	1200	wi	l	n	++	–	–	0	0
Colletotrichum gloeosporioides (Penzig) Saccardo	s	0	+	22.5-24	1200-1300	wi	all	n	++	f	+++	+	++
Sphaerotheca fuliginea (Schlechtndal: Fries) Pollaci	s	Ch	++	17.5-24	800-2200	wi	all	pm	+++	0	0	++	a
Sphaceloma sp.	u	*	+	22.5-24	1100-1800	all	l,s	s	+++	s	++	+	++
Uromyces euphorbiae Cooke & Peck	s	Am	++	17.5-24	800-2200	all	l	r	++	0	0	++	a

Table 1. Continued.

Fungi	Taxo-onomy	Prev. Recs.	Occ. Rio	Climate Temp.	Climate Precip.	Seas.	Org.	Dis.	Dam.	Culture Grow.	Culture Spor.	Potential Clas.	Potential Mycoh.
HOST: *Lantana camara* L. (Verbenaceae)				17.5-24	800-2200								
Aecidium lantanae Mayor	u	Br	+	22.5-23.5	1200-1300	all	l	r	+	0	0	0	0
Ceratobasidium sp. (?)	e	0	*	–	–	wi	l,s	wb	++	+	+	++	+
Dendryphiella aspera R.W. Barreto & J. David	ns	0	*	–	–	wi	l	n	*	s	+++	–	–
Mycovellosiella lantanae (Chupp) Deighton	s	Am	+++	17.5-24	800-2200	all	l	n	++	s	++	++	+
Perisporiopsis lantanae F.L. Stevens	s	PR	+	22.5-23	2000-2200	wi	l	so	+	s	++	0	0
Prospodium tuberculatum (Spegazzini) Arthur	s	Am	+	20.5-23	1100-2000	all	l	r	++	0	0	++	a
Pseudocercospora guianensis (Stevens & Solheim) Deighton	s	Am	+	20.5	1300	all	l	n	+	s	+	+	+
Puccinia lantanae Farlow	s	Am,Gh,Tw	+	23	2000	wi	l	r	++	0	0	++	a
Septogloeum pustuliformis R.W. Barreto	ns	0	*	–	–	all	l	n	++	0	0	++	0
HOST: *Mikania micrantha* H.B.K. (Compositae)				17.5-24	1100-2200								
Appendiculella sororcula (Spegazzini) Hansford	s	0	+	22.5	2200	wi	l	so	+	–	–	0	0
Asperisporium mikaniae (Ellis & Everhart) R.W. Barreto	nc	Am	*	–	–	wi	l	n	+	–	–	0	0
Asperisporium mikanligena (Yen & Lim) R.W. Barreto	nc	Ma	+	19	1700	wi	l	n	++	s	++	+	+
Basidiophora montana R.W. Barreto	ns	0	+	17.5-19	1400-1700	wi	l	dm	++	0	0	++	a
Cercospora mikaniicola F.L. Stevens	s	C	++	17.5-23.5	1100-2200	all	l	n	++	s	++	0	++
Fusicoccum sp.	u	0	+	23.5	1200	su	l	n	++	–	–	–	–
Mycospharella mikanifolia R.W. Barreto	ns	0	+	17.5-22.5	1400-2200	all	l	n	++	s	0	++	0
Pseudocercospora plunketti (Chupp) R.W. Barreto	nc	Me	+	17.5	1400	wi	l	n	+	s	+	0	+

Table 1. Continued.

Fungi	Taxo-onomy	Prev. Recs.	Occ. Rio	Climate Temp.	Climate Precip.	Seas.	Org.	Dis.	Dam.	Culture Grow.	Culture Spor.	Potential Clas.	Potential Mycoh.
Puccinia spegazzini de Toni	s	Am	++	17.5-24	1200-2200	all	all	r	++	0	0	++	a
HOST: *Paspalum repens* Berg (Gramineae)				20.5-23.5	1100-1300								
Bipolaris verruculosus R.W. Barreto	ns	0	++	20.5-23.5	1200-1300	all	l	n	++	s	++	–	++
Colletotrichum sp.	u	0	++	20.5-23.5	1200-1300	all	l	n	++	–	–	–	–
HOST: *Pistia stratiotes* L. (Araceae)				20.5-23.5	1100-1300								
Cercospora pistiae Nag Raj	u*	In,Au,Gh	++	20.5	1200	all	l	n	++	s	0	0	0
HOST: *Polygonum spectabile* Martins (Polygonaceae)				20.5-23.5	1100-1300								
Mycosphaerella polygoni-spectabile R.W. Barreto	ns	0	+++	20.5-23.5	1100-1300	all	l	n	++	s	0	–	0
HOST: *Typha dominguensis* Persoon (Typhaceae)				20.5-23.5	1100-1200								
Epipolaeum typharum R.W. Barreto	ns	0	++	20.5-23.5	1100-1200	all	l	so	*	0	0	0	0
Phoma sp.	u	0	+++	20.5-23.5	1100-1200	all	l	n	++	s	+++	++	+

Codes: * = observations in the text; – = none or insufficient information available.

Taxonomy: s = satisfactory; u = unsatisfactory (more research needed); ns = new species (to be described in a different article); nc = new combination (to be proposed in a different article); e = unsatisfactory but elucidation in progress.

Previous records (of the association): 0 = never recorded before; SBr = southern Brazil; Br = Brazil; Ar = Argentina; AU = Australia; Gh = Ghana; In = India; Ma = Malaysia; Me = Mexico; PR = Puerto Rico; Tw = Taiwan; Ur = Uruguay; Do = Dominican Republic; SA = South America; Am = Americas; As = Asia; Af = Africa; Oc = Oceania; C = Cosmopolitan.

Occurrences in the State of Rio de Janiero: + = rare (occurring in <20% of sites where the host was present); +++ = ubiquitous (>80% of sites where the host was present).

Climate (data from Anonymous 1978; extreme values of annual means among sites where associations occurred): temperature; in °C; precipitation: in mm.

Seasons (when associations were recorded): sp = spring; su = summer; au = autumn; wi = winter; all - all seasons.

Organ (affected plant parts): l = leaves; i = inflorescences; f = fruits; s = stems; all = all aerial parts.

Disease: r = rust; d = downy mildew; pm = powdery mildew; s = scab; = c = canker; n = necrosis; sm = smut; ts = tar spot; so = sooty mould wb = web blight.

Damage (maximum damage caused to individuals): 0 = none or insignificant; + = limited; ++ = weakening the plant; +++ = lethal.

Culture: On V8 juice agar medium.

Growth: 0 = none; s = slow growing; f = fast growing.

Sporulation: 0 = none; + = little; ++ = abundant; +++ = very abundant.

Potential: Preliminary evaluation of the potential of the fungi for the classical or mycoherbicide biological control of their weedy hosts.

Classical biological control (in case an adequate degree of specificity is proven): 0 = none; + = limited; ++ = promising.

Mycoherbicide: 0 = none; + = limited; ++ = promising; a = augmentation strategy could be attempted (for obligate parasites).

Note: The first set of climatic data for fungi on each weed block represents the range observed for the weed alone.

Table 2. Provisional identifications and observations on biological control potential of phytopathogenic fungi collected on additional weeds.[1]

Weed Surveyed	Fungi Collected
1. *Amaranthus spinosus* L. (Amaranthaceae)	*Albugo bliti* (Bivona Bernardi) Kuntze; *Alternaria* sp.; *Cercospora brachiata* Ellis & Everhart; *Phoma* sp.
2. *Ambrosia artemisiifolia* L. (Compositae)	*Oidium* sp.
3. *Bidens pilosa* L. (Compositae)	*Alternaria* sp.; *Cercospora* sp.; *Colletotrichum* sp.; *Entyloma compositarum* Farlow; *Oidium* sp.; *Plasmopara halstedii* (Farlow) Berlese & de Toni (a); *Sphaceloma bidentis* Bitancourt & Jenkins (c/m); *Uromyces* sp. (a).
4. *Cassia obtusifolia* L. & *Cassia tora* L. (Leguminosae)	*Alternaria cassiae* Jurair & Khan (m); *Cladosporium* sp.; *Colletotrichum* sp.; *Phaeoisariopsis nigricans* (Cooke) L. G. Brown & M. Jones; *Oidium* sp. (c/a).
5. *Cenchrus echinatus* L. (Gramineae)	*Bipolaris* sp. (?); *Phyllachora sphaerosperma* Winter; *Pyricularia grisea* (Cooke) Saccardo; *Puccinia cenchri* (Lagerheim) K. Vanky (c/a); Ustilaginales n. i. (c/a).
6. *Commelina benghalensis* L. (Commelinaceae)	*Bipolaris* sp.; *Cercospora* sp.; *Curvularia* sp.; *Phoma* sp.
7. *Commelina erecta* L. (Commelinaceae)	*Cercospora* sp.; *Phyllachora* sp.; *Pyricularia grisea* (Cooke) Saccardo (m); *Septoria* sp.
8. *Elephantopus mollis* H.B.K. (Compositae)	*Coleosporium vernoniae* Berkeley & Curtis (c); *Drechslera* sp.; *Pseudocercospora* sp.; *Septoria* sp.
9. *Imperata brasiliensis* Trinius (Gramineae)	Ascomycete indet.; *Cercospora* sp.; *Colletotrichum graminicola* (Cesati) Wils (m); *Curvularia* sp; *Cylindrosporium* sp. (c); *Diplodia* sp. (c/m); *Phaeoramularia* sp.; *Phyllachora* sp.; *Pleospora* sp.; *Puccinia* sp.(c/a).
10. *Ludwigia suffruticosa* (L.) Hara (Onagraceae)	*Aecidium jussieuae* Spegazzini; Ascomycete indet.; Hyphomycete indet.; *Pseudocercospora* sp.; *Septoria* sp. (1) (m); *Septoria* sp. (2) (m).
11. *Mimosa invisa* Martius (Leguminosae)	*Denticularia* sp.; *Oidium* sp.; *Pseudocercospora* sp. (c); *Uredo mimosae-invisae* Viégas (c).
12. *Mimosa pudica* L. (Leguminosae)	*Cercospora* sp. (?); *Meliola* sp.; *Oidium* sp.
13. *Panicum maximum* Jaquin (Gramineae)	*Alternaria* sp.; Ascomycete indet.; *Botryodiplodia* sp.; *Cladosporium* sp. (m); *Cerebella andropogonis* Cesati; *Colletotrichum* sp.; *Fusarium* sp.; *Guignardia* sp.; *Phaeoramularia fusimaculans* (Atkinson) X. Lin & Gou; *Phoma* sp.; *Pyricularia grisea* (Cooke) Saccardo; *Sphacelia* sp.; *Tilletia ayresii* Berkeley ex Massee; Uredinales indet. (a).
14. *Panicum pernambucense* Spreng ex Pilg. (Gramineae)	Ascomycete indet.; *Bipolaris* sp.; *Curvularia* sp.; Hyphomycete indet.; *Phyllachora* sp.; *Ustilago* sp. (a).

Table 2. Continued.

Weed Surveyed	Fungi Collected
15. *Parthenium hysterophorus* L. (Compositae)	*Alternaria zinniae* Pape; *Cercospora* sp.; *Oidium* sp.; *Septoria* sp.; *Puccinia schileana* Spegazzini var. *partheniicola* (Jackson) Lindquist (c/a).
16. *Sida acuta* L. (Malvaceae)	*Alternaria* sp. (m); *Asterina* sp.; *Cercospora sidaecola* Ellis & Everhart; *Septoria guaximae* Viégas (c/m).
17. *Sida rhombifolia* L. (Malvaceae)	*Asterina* sp; *Botryodiplodia* sp.; *Mycovellosiella sidae* (Olive) Deighton (c); *Septoria guaximae* Viégas (c/m).

[1]Code: c = showing potential as classical biological control agent; m = showing potential for development of mycoherbicide; a = could be useful for augmentation tactic projects.

m^2 which was covered in a roughly standardized period of 120 ± 30 mins. Surveys of aquatic sites took approximately twice this time and the area, which was covered by boat, was variable. Because of practical limitations, this work was concentrated mainly on fungal pathogens of aerial plant parts.

Observations on fungal pathogens collected on the target weeds outside the main sampling scheme are also included, where appropriate, in the text and tables. These include collections made by the authors in the following other Brazilian States: Espiríto Santo, Minas Gerais, Sao Paulo, Paraná, Bahia, Ceará, Amazonas and Pará.

An important part of this work was undertaken at the IMI Herbarium and 3 of the main Brazilian mycological herbaria, namely: the Departmento de Micologia of the Universidade Federal de Pernambuco–Recife; the Departmento de Microbiologia Fitotecnica of the Instituto Agronomico de Campinas–Campinas; the Instituto Biológico de Sao Paulo. In all these herbaria, registers or entry books were consulted for any records of fungi on the hosts included in this work. Attention was given to all names and common synonyms used for the plants, in order to guarantee the inclusion of all records in the final list. A comprehensive literature survey was undertaken with the aim of producing complete check-lists of fungal pathogens associated with each of the target weeds, together with their known distribution. This check-list will be published separately, but some of this information is given in Tables 1, 3 and 4.

Table 3. Pathogenic fungal flora recorded on *Imperata brasiliensis* worldwide.

Fungi	Distribution
Ascomycotina and Deuteromycotina	
Davisiella dominguensis Petrak & Ciferri	Dominican Republic
Metasphaeria (= Leptosphaeria) phyllachoracearum Petrak	South America
Myriogenospora paspali Atkinson	Brazil
Phyllachora antioquensis Chardon	Brazil
Phyllachora graminis (Persoon) Fuckel	Brazil
Phyllachora oxyspora Starback	Brazil
Phyllachora tripsacina Petrak & Ciferri	Dominican Republic
Basidiomycotina	
Puccinia infuscans Arthur & Holway	Brazil, Trinidad & Tobago
Puccinia microspora Dietel	Brazil
Puccinia posadensis Saccardo & Trotter	Brazil, Guatemala

Results and Discussion

The original number of 30 target weeds was surveyed, but because of the large volume of collections made, part of this mycoflora was only superficially studied and the work was concentrated on the mycoflora associated with the 13 weed species listed in Table 1. The

Table 4. Pathogenic fungal flora recorded on *Imperata cylindrica* worldwide. IMI numbers are given in brackets for records found in herbarium accessions but not in the world literature.

Fungi	Distribution
Ascomycotina and Deuteromycotina	
Ascochyta imperatae Punithalingam	Malaysia, Nigeria/New Guinea (IMI 117486)
Aulographum maximum Massee	New Guinea
Balansia sp.	India (IMI 238710)
Bipolaris sacchari (Butler) Shoemaker	India
B. zeae Sivanesan	Australia
Cacumisporium sp.	New Guinea
Caenothyrium (= *Actinopletis*) *alangalang* Theissen & Sydow	Philippines
Capnodium sp.	Papua New Guinea
Cercospora imperatae (H. & P. Sydow) Sawada	China, India, Philippines, Taiwan
Cerebella andropogonis Cesati	Malaysia
Claviceps imperatae Tandra & Kawatani	Japan
C. purpurea (Fries) Tulasne	Korea
Cochliobolus geniculatus Nelson	Brunei/Malaysia (IMI 154092)
C. heterostrophus (Drechsler) Drechsler	Malaysia (IMI 292562)
C. pallescens (Tsuda & Veyama) Sivanesan	Malaysia
C. stenospilus Mat & Yam	India
Colletotrichum caudatum (Saccardo) Peck	Brunei
C. demiatum (Persoon *ex* Fries) Grove	India
C. graminicola (Cesati) Wils	Malaysia/Papua New Guinea (IMI 199193), Solomon Islands
C. imperatae J. Politis	Greece
Deightoniella africana Hughes	Ghana, Togo/Sierra Leone (IMI 41188)
Didymaria (= *Ramularia*) sp.	Malaysia
Dinemasporium sp.	Malaysia
Ephelis oryzae Sydow	India
Giberella imperatae C. Booth & C. Prior	Papua New Guinea/Australia (IMI 172501), Sabah (IMI 291931)
Helminthosporium maydis Nish & Miyabe	China
H. rostratum Drechsler	India
H. sacchari (Van Breda de Haon) Butler	India
Lisea revocans Saccardo	Philippines
Lophodermium sp.	Malaysia
Massalongiella imperatae Rehm	Philippines
Meliola imperatae Sydow	Philippines

Table 4. Continued.

Fungi	Distribution
M. sacchari Sydow	Philippines
Micropeltis alang-alang Raciborski	Indonesia (Java)
Microthyrium imperatae H. & P. Sydow	Philippines
Monodisma fragilis Alcorn	Australia/New Guinea (IMI 77479), Sierra Leone (IMI 41185, 8020, 8021)
Mycosphaerella sp.	New Guinea
M. imperatae Sawada	Taiwan
Paraphaeosphaeria michiotii (Westendorp) O. Erikson	Uganda/Nigeria (IMI 81793)
Phyllachora imperatae Sydow	India, Philippines
P. imperaticola Sawada	China, Taiwan
P. oxyspora Starback	Australia/India (IMI 201001)
Pirostoma sp.	Malaysia, Papua New Guinea/Togo (IMI 39675)
Pyricularia grisea (Cooke) Saccardo	Bangladesh/Egypt (IMI 182335)
Ramulispora sp.	Nigeria
Sirosperma hypocrellae Sydow	Papua New Guinea
Stagonospora simplicior Saccardo & Berlese	Australia, Guinea
Vermicularia (= *Colletotrichum* ?) *culmifraga* Fries	Egypt
Basidiomycotina	
Himantia (= *Cylindrobasidium*) *stellifera* Johnston	South Africa
Marasmius pulcher (Berkeley & Broome) Petch	Malaysia
Puccinia eucomis Doidge	Sudan
P. fragosoana Beltran	Ghana, Guinea, Malawi, Nigeria, Sierra Leone, Spain, Sudan, Thailand
P. imperatae (Magnus) Poiraut	Cyprus, Egypt, France, South Africa, Spain, Sudan, Tanzania, Turkey
P. microspora Dietel	Argentina, Bangladesh, China, India, New Guinea
P. rufipes Dietel	Australia, China, Egypt, Ghana, India, Japan, Malaysia, New Caledonia, Pakistan, Papua New Guinea, Philippines, Sierra Leone, South Africa, Sri Lanka, Taiwan, Thailand/Burma (IMI 169369), Nepal (IMI 328462), Zimbabwe (IMI 64339)
P. versicolor Dietel & Holway	Sudan
Septobasidium sp.	India (IMI 200126)
Sphacelotheca nankinensis Zundel	China
S. schweinfurthiana (Thuemen) Saccardo	Algeria, Cyprus, Egypt, Ghana, Greece, India, Iran, Iraq, Israel, Italy, Libya, Malaysia, Morocco, Nigeria, Pakistan, Portugal, Uganda/Mauritania

Table 4. Continued.

Fungi	Distribution
	(IMI 267300)
Thanatephorus cucumeris (A.B. Frank) Donk	China, Taiwan
Uredo imperatae P. Magnus	Israel
U. consimilis Sydow	South Africa
U. imperatae Mundkur	India
U. nepalensis Lindroth	China
U. scitaminea Sydow	South Africa

information and samples of the fungi found associated with the other weeds (listed in Table 2) are still being processed.

Nine out of 56 fungal species studied in detail during this work, are considered to be new to science, and among these some, such as *Basidiophora montana* R.W. Barreto (Barreto and Dick 1991), are considered to be promising as biological control agents. Three new combinations are proposed. More significant, perhaps, is the number (25) of fungal/host associations recorded here for the first time. For some of the fungi, morphology alone is not sufficient for species delimitation and additional information, on physiology, chemistry and pathogenicity, will be necessary to make a taxonomic decision. In some cases, examination of fresh material will also be necessary, such as for *Sphaceloma* sp. on *Euphorbia hirta* L. (Euphorbiaceae). *Cercospora pistiae* Nag Raj, a fungus that attacked *Pistia stratioites* L. (Araceae) was found to be morphologically identical to *Cercospora canescens* Ellis & Martin (a plurivorous *Cercospora* species that attacks mainly leguminous hosts) and the taxonomic status of this fungus is considered as still being unsatisfactory. *Fusicoccum* sp. was found only once attacking a single plant of *Mikania micrantha* H.M.B. (Compositae) and belongs to a relatively large genus containing many non-specific pathogens that needs complete taxonomic revision (Punithalingham, E., personal communication, 1990). The lack of adequate identification of these fungi hampered the assessment of their known distribution from the literature and herbarium records. Work is also continuing towards the elucidation of the taxonomy of the *Puccinia* complex on *Cyperus rotundus* L. (Cyperaceae). Seven different species of *Puccinia* have been described in the literature associated with this weed (widely regarded as the world's worst weed). Type material of these is being examined and a great degree of morphological similarity has already been detected among these rust species, most of which appear to have been erected purely on a geographical basis. The elucidation of the taxonomy of the *Puccinia* complex on *C. rotundus* is critical for any evaluation of classical biological control potential for these fungi.

Mycovellosiella perfoliata (Ellis & Everhart) Muntañola on *Chromolaena odorata* (L.) King & Robinson (Compositae) and *Septogloeum pustuliformis* R.W. Barreto on *Lantana camara* L. (Verbenaceae) are examples of associations that appeared to be rare during the field survey but which were later, during the more intensive laboratory study, recognized as having been overlooked on a number of occasions. This was due to the occurrence of these fungi in association with other more conspicuous fungal pathogens.

The following fungi were found in the survey only outside the State of Rio de Janeiro: *Ceratobasidium* (Corticiaceae) sp. and *Dendryphiella aspera* R.W. Barreto & J. David on *L. camara*, the former was discovered recently in the States of Amazon and Bahia, and the latter in the State of Sao Paulo; *Asperisporium mikaniigena* (Yen & Lim) R.W. Barreto on *M. micrantha* (only from the State of Paraná).

Climatic data, presented in Table 1, are the range of mean annual temperatures and precipitation of wetter/dryer, warmer/colder sites in Rio where the associations were found. It does not, therefore, represent the true limits of tolerance of these fungi. These data give only an indication of the type of climate the fungi are adapted to. The ranges of mean annual temperatures and precipitation of terrestrial sites in Rio were limited to 17.5-24°C, 800-2200 mm, while that of the aquatic sites were limited to 20.5-23.5°C, 1100-1300 mm. No climatic data were available for sites outside the State of Rio de Janeiro.

Repetitive associations between fungal presence and disease symptoms were used as circumstantial evidence of pathogenicity, but it is acknowledged that the pathogenic status of most of the fungi found requires confirmation. For some of these fungi, pathogenic status was considered too doubtful even for a preliminary ranking. These are indicated in Table 1 with an asterisk.

Wapshere's (1974) definition of effective biological control agents "those which play a major role in controlling the distribution and abundance of the plant after allowances have been made for minor ecological differences and for the part played by parasitization, predation and disease," gives some idea of the amount of subjectivity involved in deciding about an organism's potential as a biological control agent based on field observations. The most effective biological control agent can appear in the field to be totally insignificant. A classical example is that of *Cyrtobagus salviniae* Calder & Sands (Coleoptera: Curculionidae), a weevil which according to the discoverer was restricted to a small pond habitat in Brazil, feeding on salvinia, its water weed host, without producing any noticeable impact on that population (Forno, I.W., personal communication, 1991). Nevertheless, its introduction into Australia, Papua New Guinea and Sri Lanka resulted in one of the most spectacular reductions of a weed population ever achieved by a biological control agent.

Effectiveness cannot, therefore, be determined "a priori", with much precision, but a tentative estimation of biological control potential was made nevertheless. This may be used, but with the understanding that it is mainly an "unscientific" combination of empiricism and common sense.

Phatak *et al.* (1983, 1987) demonstrated that obligate parasites such as rust fungi could be mass-produced under controlled conditions on susceptible hosts, and the harvested inoculum applied as a mycoherbicide. This variation of the mycoherbicide strategy could be employed for some of the obligate parasites found in the survey, as indicated in Tables 1 and 2.

For some weeds, the survey revealed a poor pathogenic mycoflora, suggesting a lack of natural enemies which could explain the weedy status of the plant. *Ambrosia artemisiifolia* L. (Compositae) is a case in point, and is a weed of increasing importance in the uplands of Rio and other subtropical regions of Brazil. It is considered to be native to North America. A total of 34 fungal pathogens are listed in the literature and in herbarium accessions as being associated with this weed. Twenty-nine of these have been recorded from North America. These could prove to be effective agents for classical biological control of this weed in Brazil and elsewhere, and work along these lines should be encouraged. Similarly, *Commelina benghalensis*, an important weed introduced from the Old World, also has a poor mycoflora associated with it in Rio–4 fungal pathogens as compared to a total of 25 known fungal pathogens.

A depauperate pathogenic mycoflora on *Eichhornia crassipes* (Martius) Solms-Laubach (Pontederiaceae) (the World's worst aquatic weed and regarded as being of Brazilian origin), is interpreted here as an indication that the State of Rio de Janeiro is not in fact part of the area of origin/diversification of the plant. This is possibly also true for *Pistia stratioites* and *Polygonum spectabile* Martins (Polygonaceae)

Among the fungi listed in Table 2, some are marked as especially promising biological control agents, due to the damage they cause, their apparently restricted host range and their culturability. All fungi in Table 2 were collected during the survey in the State of Rio de Janeiro. The only exceptions are: *Alternaria* sp. on *S. carpinifolia*, which was collected on the banks of the Rio Negro–State of Amazonas, and *Cladosporium* sp. on *Panicum maximum* Jaquin (Gramineae) which was collected at a roadside (Manaus-Itacoatiara) in the same State.

Imperata brasiliensis Trin. is an important grassy weed, native to Brazil and common in dry, acid soils, which is closely related to *I. cylindrica* (L.) Beauv., one of the worst weeds in the Old World. They have a very similar overall appearance and their taxonomic separation is based mainly on differences in the number of stamens. (Renvoize, S., personal communication, 1990). The field, literature and herbaria surveys suggest that these 2 weeds have completely separate pathogenic mycofloras associated with them (see Tables 2, 3 and 4). In the literature (Klinkovsky 1970; Quimby 1982), there are examples of some devastating epiphytotics that have occurred after the inadvertent "new encounter" of a very susceptible host with a pathogen pre-adapted to it, but geographically separated from it. Provoking such a "new encounter" in order to fight weed infestations is a strategy never attempted before. The *Imperata* weeds would be excellent candidates for such an attempt.

In conclusion, this work has signaled the presence in Rio de Janeiro, and other Brazilian states, of a range of fungal pathogens with potential as biological control agents of 22 of the weeds included in the survey. It has also revealed the depauperate pathogenic mycoflora of some of the exotic weeds established in Brazil and, as a consequence, highlighted the opportunities for classical biological control. It is considered that general projects such as this, as well as others directed to specific fungal/weed associations, should be encouraged in the subtropics and tropics, both for their academic as well as practical value.

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