

Phyllosticta—an overview of current status of species recognition

Saowanee Wikee · Dhanushka Udayanga · Pedro W. Crous · Ekachai Chukeatirote · Eric H. C. McKenzie · Ali H. Bahkali · DongQin Dai · Kevin D. Hyde

Received: 17 October 2011 / Accepted: 18 October 2011 / Published online: 23 November 2011
© Kevin D. Hyde 2011

Abstract *Phyllosticta* is an important coelomycetous plant pathogenic genus known to cause leaf spots and various fruit diseases worldwide on a large range of hosts. Species recognition in *Phyllosticta* has historically been based on morphology, culture characters and host association. Although there have been several taxonomic revisions and enumerations of species, there is still considerable confusion when identifying taxa. Recent studies based on molecular data have resolved some cryptic species and

some novel taxa have been discovered. However, compared to the wide species diversity and taxonomic records, there is a lack of molecular studies to resolve current names in the genus. A phylogenetic tree is here generated by combined gene analysis (ITS, partial actin and partial elongation factor 1 α) using a selected set of taxa including type-derived sequences available in GenBank. Life modes, modal lifecycle and applications of the genus in biocontrol and metabolite production are also discussed. We present a selected set of taxa as an example of resolved and newly described species in the genus and these are annotated with host range, distribution, disease symptoms and notes of additional information with comments where future work is needed.

S. Wikee · D. Udayanga · E. Chukeatirote · D. Dai · K. D. Hyde
Institute of Excellence in Fungal Research,
Mae Fah Luang University,
Chiang Rai 57100, Thailand

S. Wikee · D. Udayanga · E. Chukeatirote · D. Dai · K. D. Hyde
School of Science, Mae Fah Luang University,
Chiang Rai 57100, Thailand

P. W. Crous
CBS–KNAW Fungal Biodiversity Centre,
Uppsalsalaan 8,
3584 CT Utrecht, The Netherlands

E. H. C. McKenzie
Landcare Research,
Private Bag 92170, Auckland Mail Centre,
Auckland 1142, New Zealand

D. Udayanga
State Key Laboratory of Mycology, Institute of Microbiology,
Chinese Academy of Sciences,
No 3 1st West Beichen Road, Chaoyang District,
Beijing 100101, People's Republic of China

A. H. Bahkali · K. D. Hyde (✉)
College of Science, Botany and Microbiology Department,
King Saud University,
Riyadh, Saudi Arabia
e-mail: kdhyde3@gmail.com

Keywords Biocontrol · Endophyte · *Guignardia* · Leaf spot · Morphology · Molecular phylogeny · Secondary metabolites

Introduction

The genus *Phyllosticta* Pers. ex Desm. is a taxonomically confused group of microfungi comprising mostly important phytopathogens with a wide host range (van der Aa 1973; van der Aa and Vanev 2002). Although the generic concept of *Phyllosticta* has been refined and species names were enumerated in a monographic treatment by van der Aa and Vanev (2002), species recognition still remains problematic (Hyde et al. 2010a, b; Glienke et al. 2011). Several species of *Phyllosticta* have also been reported as endophytes and saprobes (van der Aa and Vanev 2002; Baayen et al. 2002; Okane et al. 2003; Wulandari et al. 2009, 2010; Glienke et al. 2011). Species of *Phyllosticta* (teleomorph *Guignardia* Viala & Ravaz) cause leaf spot symptoms and fruit diseases on a range of hosts including some economically important

dently from each other, and only a few *Phyllosticta* species have been linked to their *Guignardia* teleomorphs. Consequently, their classification is confusing and the relation between host range and disease are often poorly understood (van der Aa 2002)

Using *Phyllosticta* versus *Guignardia*

The name *Phyllosticta* (asexual state) and *Guignardia* (sexual state) have been used separately following the dual classification system used by mycologists over several decades (Hawksworth 2004; McNeil et al. 2006; Shenoy et al. 2007, 2010). For instance *Phyllosticta musarum* (Cooke) Aa and *Guignardia musae* Racib. are the same biological species but have different names, *P. musarum* being the asexual state and *G. musae* being the sexual state (van der Aa 1973; Wulandari et al. 2010). However with the use of molecular data it is now possible to link asexual and sexual states (Berbee and Taylor 2001) and the use of the dual nomenclature system of classification in fungi has become redundant (Hawksworth 2011). Therefore a single name should be adopted and there are various views to which names should be followed, i.e. the oldest, the sexual state name, the most conserved name, and view maintaining both names (Berbee and Taylor 2001; Seifert and Rossman 2010; Hyde et al. 2011). Our view is that we should generally adopt the oldest name for each genus, which will soon be enforced in the International Code of Nomenclature for algae, fungi and plants, but also taking into account which name is the most important and commonly used. *Phyllosticta* Pers. (1818) is a much older name than *Guignardia* Viala & Ravaz (1892) and generally *Phyllosticta* species are known to cause important diseases (e.g. leaf spot, citrus black spot, black rot of horse chestnut). There are also many more species of *Phyllosticta* than *Guignardia*. There are exceptions, for example *Guignardia candeloflamma* K.D. Hyde is only known in its teleomorph state (Wulandari et al. 2010a), while banana freckle is caused by both states (Wulandari et al. 2010b). Because *Phyllosticta* is the oldest name and generally more important as the causal agent of disease we chose to adopt this name and treat all *Guignardia* species as synonyms of *Phyllosticta*, in the sense of Glienke et al.

(2011). Because of this decision we use the name *Phyllosticta* throughout this review unless we specifically refer to a *Guignardia* species. *Leptodothiorella*, which previously represented the spermatial state of some *Phyllosticta* species (e.g. *Leptodothiorella aesculicola* (Sacc.) Sivan.), are also treated as synonyms of *Phyllosticta* (van der Aa 1973).

Morphological characteristics to differentiate species

Phyllosticta pycnidia are usually globose, subglobose or tympaniform, flattened above, and closely connected with the subepidermal pseudostroma (Fig. 3a, b). They are mostly unilocular but occasionally may be multilocular (van der Aa 1973). The conidia are commonly hyaline, one-celled, ovoid, obovate or ellipsoid, or short cylindrical, seldom pyriform, globose or subglobose, 10–25 µm long, and usually covered by a slime layer and bearing a single apical appendage (Fig. 3c) (van der Aa 1973). Cultural characteristics when grown on specific media may also be used as differentiating characters. In the case of *P. citricarpa* colonies can be characterised after 14 days at 25°C in the dark on OA as flat, spreading, olivaceous-grey, becoming pale olivaceous-grey towards the margin, with sparse to moderate aerial mycelium; surrounded by a diffuse yellow pigment in the agar medium (Wulandari et al. 2009).

The sexual state *Guignardia* can be characterized by erumpent ascomata, which are globose to pyriform in section, often irregularly shaped, unilocular, and with a central ostiole forming by dehiscence when mature. The peridium is thin, comprising a few layers of angular cells. Asci are 8-spored, bitunicate, clavate to broadly ellipsoid, with a wide, slightly square apex, tapering gradually to a small pedicel, and with a well-developed ocular chamber. Ascospores are ellipsoid to limoniform, sometimes slightly elongated, aseptate, hyaline, often guttulate or with a large central guttule, and some have mucilaginous polar appendages (van der Aa 1973; Wulandari et al. 2011, Fig. 3d–f).

A spermatial state is often present in the life cycle of *Guignardia* species, and readily forms in culture. Spermatia are cylindrical to dumbbell-shaped with guttules at each end (Fig. 3g). In the past several spermatial states were

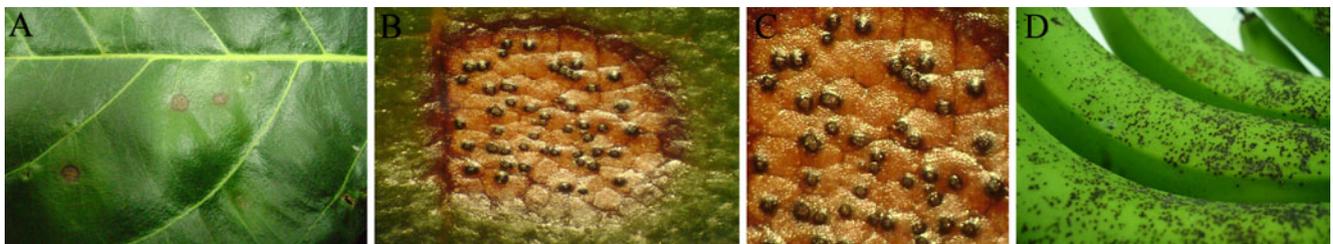


Fig. 1 *Phyllosticta* sp. on living leaf of jackfruit. **a** Leaf spots. **b–c** Lesion on adaxial surface. **d** Banana freckle disease

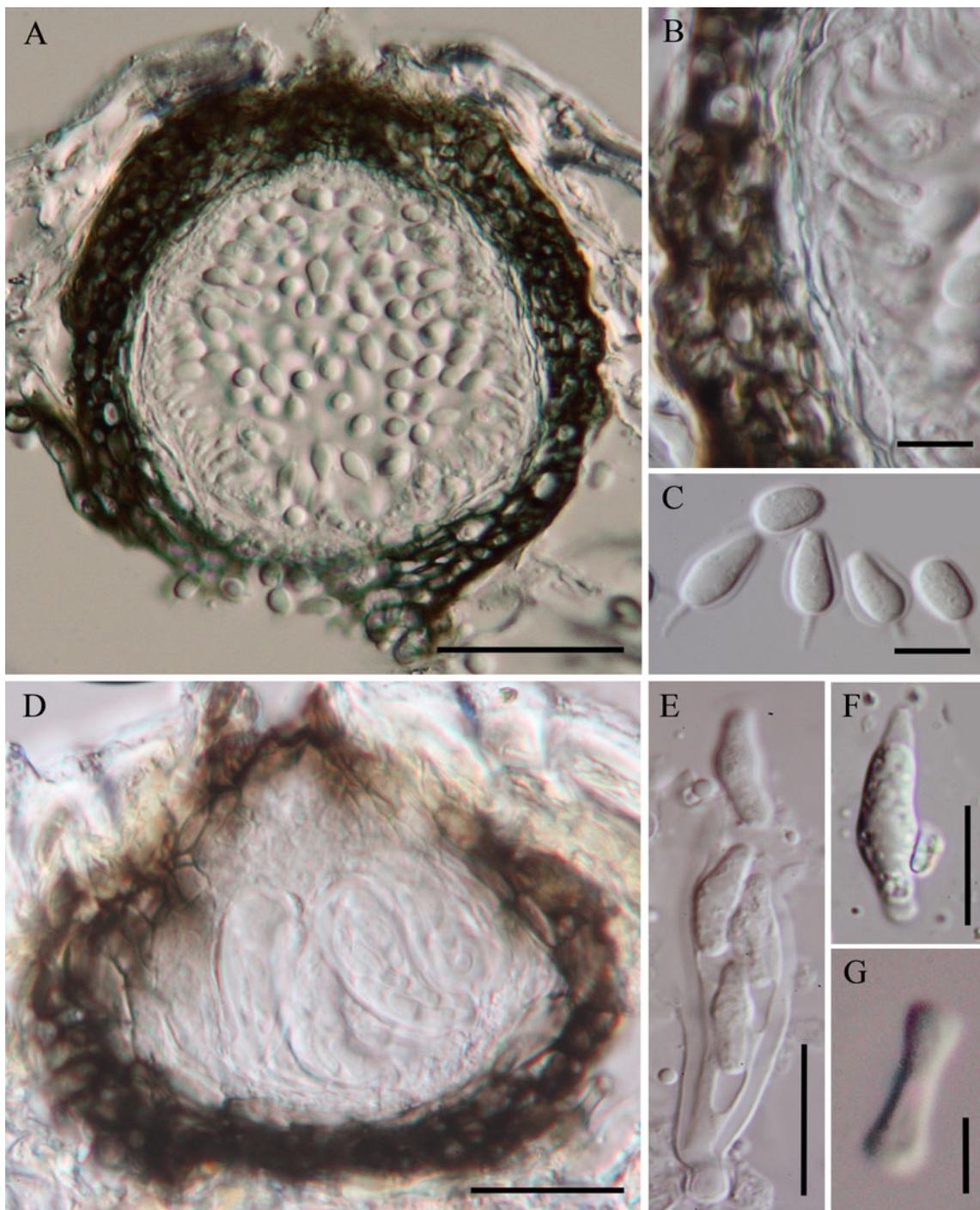


Fig. 3 Comparison of *Phyllosticta* and *Guignardia* states. **a** Vertical section through pycnidium. **b** Pycnidial wall with conidiogenous cells. **c** Conidia. **d** Section of ascoma. **e** Bitunicate and fissitunicate ascus. **f**

Ascospores. **g** *Leptodothiorella* spermatial state. Scale Bars: **a, b, d, e** = 50 μm , **c, f, g** = 10 μm

phylogenetic analysis of *Phyllosticta* strains from various host plants. Results from this study revealed isolates to cluster in two subgroups based on molecular data as, (1) cultures from a wide range of host plants mainly derived as endophytes from symptomless plants (*P. capitalensis* complex, see below) and (2) relatively host-specific

strains (often isolated as foliar pathogens from diverse plants).

ITS-RFLP and ITS sequence analysis were used to examine genetic variation of foliar endophytic *Phyllosticta* strains from different tropical trees (Pandey et al. 2003). Although ITS-RFLP failed to infer genetic diversity among

isolates used, the ITS phylogram supported the identity of *P. capitalensis* as a common foliar endophyte and pathogen with wide range of hosts. In a similar study, the diversity of strains of *Guignardia* (or *Phyllosticta*) was evaluated using rDNA ITS sequence data (Okane et al. 2003). *Guignardia endophyllicola* (anamorph *Phyllosticta capitalensis*) was shown to have an extensive host range. The taxon was identified in 53 isolates from the same number of different plants belonging to 43 genera. Phylogeny based on rDNA ITS sequence analyses derived from 18 tropical endophytic strains from different plants confirmed conspecificity of the Brazilian isolates with *Phyllosticta capitalensis* (as *G. mangiferae*) (Rodrigues and Sieber. 2004). In the ITS sequence comparison, some *Guignardia* and *Phyllosticta* strains from unrelated hosts were more closely related than other isolates derived from closely related plants. However, the diversity across the wide range of hosts should be evaluated by incorporating more genes in analyses and isolating strains from a wide range of hosts in future studies.

The population structure and phylogenetic relationships of *Guignardia citricarpa* (citrus black spot) were investigated by Baayen et al. (2002) using ITS, AFLP and morphological comparison. The observations supported the historic distinction between slowly growing pathogenic isolates and fast growing non-pathogenic isolates, which proved to belong to *P. capitalensis* (as *G. mangiferae*), the ubiquitous endophyte reported in various studies (Okane et al. 2003; Rodriguez et al. 2009; Glienke et al. 2011). Numerous synonyms for *P. capitalensis* have been used in earlier studies, reviewed in this section. We have used the name as it appeared in the original publication, although the need for careful refinement using the currently accepted name is recommended.

Studies employing multi-locus analyses in *Phyllosticta*

Identification of *Phyllosticta* species is problematic as few characters are available to differentiate species. Although ITS sequence data have been widely used for species discrimination, multi-locus phylogenies might resolve cryptic species (Wulandari et al. 2009). A combined phylogenetic analysis based on the rDNA ITS, translation elongation factor 1 (TEF1), and actin (ACT) genes resolved three species, namely *P. mangiferae*, *P. citricarpa* and a new species, *P. citriasiana* (Wulandari et al. 2009), the latter causing tan spot of *Citrus maxima* in Asia. Glienke et al. (2011) investigated the genetic diversity of endophytic and pathogenic *Phyllosticta* species, with particular emphasis on *Phyllosticta citricarpa* and *Guignardia mangiferae* occurring on *Citrus*. Combined DNA sequence analysis based on rDNA ITS, translation elongation factor 1 (TEF1), actin (ACT) and glyceraldehyde-3-phosphate dehydrogenase (GPDH) genes resolved nine well-supported clades

related to seven known species and two apparently undescribed species. They have designated epitypes for *P. citricarpa* collected from Australia and *Phyllosticta capitalensis* collected from Brazil (Glienke et al. 2011). Furthermore, *P. brazilinae*, *P. bifinariae* and *P. citribraziliensis* were described as novel species based on morphology and a multilocus phylogeny. The combined gene analysis further revealed that the allocation of various synonyms for the endophytic, non-pathogenic isolates occurring on wide range of hosts would be more correctly referred to as *P. capitalensis*. Further work is needed, however, to resolve whether this taxon is a complex of cryptic species.

Multi-locus phylogeny inferred from available sequences in GenBank

A selected set of ITS rDNA, ACT, and TEF1 sequences, including the available ex-type, and ex-epitype materials were downloaded from GenBank (Table 1). The sequences were aligned using Bioedit, alignment was optimized manually and the genes are combined to perform phylogenetic analysis. Parsimony analysis was carried out by PAUP v. 4.0b10 (Swofford 2002). Ambiguously aligned regions were excluded from all analyses and the gaps were treated as missing data. Trees were figured in Treeview (Page 1996). One of the most parsimonious trees generated from combined gene analysis for 35 strains is provided (Fig. 4).

The phylogenetic tree based on GenBank sequences including sequences originating from seven ex-type cultures, and other sequences are identified as appeared in recent publications. We have used 35 isolates in the multilocus phylogenetic tree, as there is a lack of sequence data of all three genes for all known ex-type cultures, some of which therefore had to be excluded from the analyzed dataset (see Table 1). However we recommend the improvement of the multi-locus phylogenetic analysis by using more phylogenetically informative genes, and more ex-type isolates in future work. Incorporation of more ex-type sequences will accelerate the accurate identification of other species from various geographical locations and a wide range of hosts.

Ecology of *Phyllosticta* species

Phyllosticta species are important plant pathogens and, although taxa are also commonly identified as endophytes (Baayen et al. 2002; Rodrigues and Sieber 2004), a few species have also been reported as saprobes. In some cases a species may occupy more than one life mode. For example, *P. capitalensis* was originally described on *Stanhopea* (*Orchidaceae*) from Brazil as a fungal pathogen. Recently, Silva et al. (2008) reported that *P. capitalensis*

Table 1 Details of *Guignardia* and *Phyllosticta* isolates and GenBank accession number of their sequence data

Species	Strain ^a	Substrate	Country	Collector(s)	ITS	ACT	TEFI
<i>Guignardia bidwellii</i>	CBS 111645	<i>Parthenocissus quinquefolia</i>	USA	G. Carroll	EU683672	–	EU683653-
<i>Guignardia citricarpa</i>	CBS 102345	<i>Citrus aurantium</i> , lesion on peel	Brazil	–	FJ538311	FJ538427	FJ538369
<i>Guignardia citricarpa</i>	CBS 122482	<i>Citrus sinensis</i>	Zimbabwe	L. Huisman	FJ538317	FJ538433	FJ538375
<i>Guignardia citricarpa</i>	CBS 122384	<i>Citrus limon</i>	South Africa	M. Truter	FJ538316	FJ538432	FJ538374
<i>Guignardia citricarpa</i> (ex-epitype)	CBS 127454	<i>Citrus limon</i>	Australia	S.L. Willingham	JF343583	JF343667	JF343604
<i>Guignardia mangiferae</i>	CBS 115046	<i>Myradcrodrum urundeuva</i> , leaf or bark	Brazil	K.F. Rodrigues	FJ538322	FJ538438	FJ538380
<i>Guignardia mangiferae</i>	CBS 115047	<i>Aspidosperma polyneuron</i> , leaf or bark	Brazil	K.F. Rodrigues	FJ538323	FJ538439	FJ538381
<i>Guignardia mangiferae</i>	CBS 114751	<i>Spondias mombin</i> , leaf or bark	Brazil	K.F. Rodrigues	FJ538349	FJ538465	FJ538407
<i>Guignardia mangiferae</i>	CBS 115049	<i>Bowditchia nitida</i> , leaf or bark	Brazil	K.F. Rodrigues	FJ538324	FJ538440	FJ538382
<i>Guignardia mangiferae</i>	IMI 260576	<i>Mangifera indica</i> , leaf endophyte	India	M.V. Lekshmi	JF261459	JF343641	JF261501
<i>Guignardia psidii</i>	CBS 100250	<i>Psidium guajava</i> , fruit	Brazil	C. Glienke	FJ538351	FJ538467	FJ538409
<i>Guignardia vaccinii</i>	CBS 126.22	<i>Oxycoccus macrocarpus</i>	U.S.A	–	FJ538353	FJ538469	FJ538411
<i>Phyllosticta bifrenariae</i> (ex-type)	VIC30556; CBS 128855	<i>Bifrenaria harrisoniae</i> , living leaf	Brazil	O. Pereira	JF343565	JF343649	JF343586
<i>Phyllosticta brazilianae</i>	LGMF 333	<i>Mangifera indica</i> , leaf endophyte	Brazil	C. Glienke	JF343574	JF343658	JF343595
<i>Phyllosticta brazilianae</i>	LGMF 334	<i>Mangifera indica</i> , leaf endophyte	Brazil	C. Glienke	JF343566	JF343650	JF343587
<i>Phyllosticta brazilianae</i> (ex-type)	CBS 126270	<i>Mangifera indica</i> , leaf endophyte	Brazil	C. Glienke	JF343572	JF343656	JF343593
<i>Phyllosticta capitataensis</i>	CBS 100175	<i>Citrus</i> sp., healthy leaf	Brazil	C. Glienke	FJ538320	FJ538436	FJ538378
<i>Phyllosticta capitataensis</i>	CBS 123373	<i>Musa paradisica</i>	Thailand	N. F. Wulandari	FJ538341	FJ538457	FJ538399
<i>Phyllosticta capitataensis</i> (ex-epitype)	CBS 128856	<i>Stanhoepa graveolens</i>	Brazil	O.L. Pereira	JF261465	JF343647	JF261507
<i>Phyllosticta citriasiatica</i>	CBS 120488	<i>Citrus maxima</i>	Thailand	J. de Gruyter	FJ538354	FJ538470	FJ538412
<i>Phyllosticta citriasiatica</i>	CBS 123393	<i>Citrus maxima</i>	Vietnam	J. de Gruyter	FJ538358	FJ538474	FJ538416
<i>Phyllosticta citriasiatica</i>	CBS 123372	<i>Citrus maxima</i>	Vietnam	J. de Gruyter	FJ538357	FJ538473	FJ538415
<i>Phyllosticta citriasiatica</i> (ex-type)	CBS 120486	<i>Citrus maxima</i>	Thailand	J. de Gruyter	FJ538360	FJ538476	FJ538418
<i>Phyllosticta citribrazilensis</i> (ex-type)	CBS 100098	<i>Citrus</i> sp., healthy leaves	Brazil	C. Glienke	FJ538352	FJ538468	FJ538410
<i>Phyllosticta citribrazilensis</i>	LGMF09	<i>Citrus</i> sp., healthy leaves	Brazil	C. Glienke	JF261436	JF343618	JF261478
<i>Phyllosticta citricarpa</i>	CBS 122348	<i>Citrus sinensis</i> , lesions on fruit	Zimbabwe	L. Huisman	FJ538315	FJ538431	FJ538373
<i>Phyllosticta citricarpa</i>	CBS 127455	<i>Citrus sinensis</i>	Australia	S.L. Willingham	JF343584	JF343668	JF343605
<i>Phyllosticta citricarpa</i> (ex-epitype)	CBS 127454	<i>Citrus limon</i>	Australia	S.L. Willingham	JF343583	JF343667	JF343604
<i>Phyllosticta cussonia</i>	CPC 14873	<i>Cussonia</i> sp.	South Africa	P.W. Crous	JF343579	JF343663	JF343600
<i>Phyllosticta cussonia</i>	CPC 14875	<i>Cussonia</i> sp.	South Africa	P.W. Crous	JF343578	JF343662	JF343599
<i>Phyllosticta hypoglossi</i>	CBS 101.72	<i>Ruscus aculeatus</i> , living leaf	Italy	W. Gams	FJ538365	FJ538481	FJ538423
<i>Phyllosticta hypoglossi</i>	CBS 434.92	<i>Ruscus aculeatus</i>	Italy	W. Gams	FJ538367	FJ538483	FJ538425
<i>Phyllosticta hypoglossi</i>	CBS 167.85	<i>Ruscus hypoglossum</i>	Italy	W. Gams	FJ538366	FJ538482	FJ538424
<i>Phyllosticta ovaniana</i>	CBS 776.97	<i>Brabejum stellatifolium</i>	South Africa	A. den Breeÿen	FJ538368	FJ538484	FJ538426
<i>Phyllosticta spinarum</i>	CBS 292.90	<i>Chamaecyparis pisifera</i>	France	M. Morelet	JF343585	JF343669	JF343606
<i>Phyllosticta spinarum</i>	CBS 937.70	<i>Hedera helix</i> , leaf litter	Italy	W. Gams	FJ538350	FJ538466	FJ538408

^a CBS: Centraalbureau voor Schimmelfcultures, Utrecht, The Netherlands; CPC: Culture collection of Pedro Crous, housed at CBS; IMI: International Mycological Institute, CABI-Bioscience, Egham, Bakenham Lane, UK; LGMF: Culture collection of Laboratory of Genetics of Microorganisms, Federal University of Paraná, Curitiba, Brazil; VIC: Culture Collection of Federal University of Vicosa, Vicosa, Brazil.

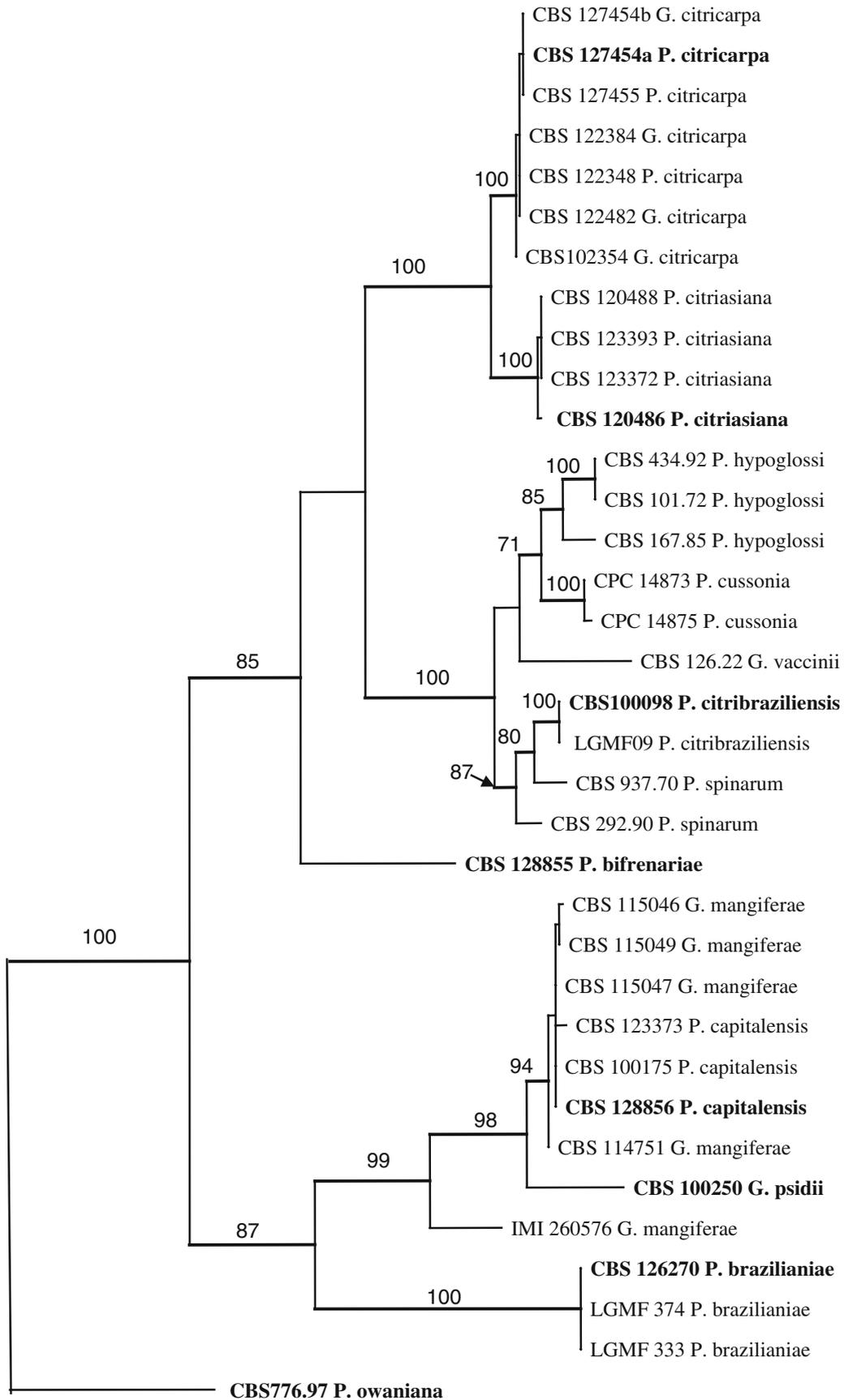


Fig. 4 Phylogram generated from the parsimony analysis based on combined rDNA ITS, ACT, TEF1 sequence data for *Phyllosticta* spp. downloaded from GenBank. Strictly consensus branches are thickened and bootstrap support values >70% are shown below or above the branch. Cultures derived from type specimens are in bold. The tree is rooted with *Phyllosticta owaniana*

caused disease of leaves and pseudobulbs of *Bifrenaria harrisoniae* (Orchidaceae) in Brazil. *Phyllosticta capitalensis* has also been reported as an endophyte on ericaceous plants in Japan by Okane et al. (2001), and non-pathogenic strains have been isolated from *Citrus* sp. (Table 2) (Baayen et al. 2002; Glienke et al. 2011).

Host specificity of *Phyllosticta* species and disease symptoms

Phyllosticta species may cause leaf spots on many plant species and it is not clear if they are generalists or host-specific; this may depend on the particular species or their life style. It is known that several species that cause diseases are host, genus or family specific, while endophytes may be generalists. For example, *P. sphaeropoidea* Ellis & Everh. causes leaf blotch disease specific to horse chestnut in Europe and North America (Hudson 1987). *P. citricarpa* causes leaf spot disease of *Citrus* species, while *P. citriasiana* can infect fruits of *Citrus maxima* (pomeloes), and causes tan spot and has only been isolated from pomeloes, but has never been found from lemons, mandarins and oranges, and *Phyllosticta musarum* is specific on *Musa* spp. (Wulandari et al. 2009, 2010, 2011). *P. capitalensis* is an endophyte of a wide range of hosts (Okane et al. 2003; Baayen et al. 2002).

Knowledge of disease symptoms on hosts are important for field identification by taxonomists as well as plant pathologist interested in disease occurrence, management and distribution. Generally, *Phyllosticta* species cause necrotic lesions on leaves, which are characteristically small, often 1–2 mm in diameter, circular, brown in the middle and dark brown or sometimes reddish at the margin (Fig. 1a). One to more than 10 pycnidia are often found in

one lesion (Fig. 1b, c). Pycnidia on leaves are usually black, globose or subglobose, and semi-immersed (Fig. 1c). After infection by *Phyllosticta* the leaf may become dry in the centre of the lesion, causing the infected tissue to drop out, forming a hole, and hence this is known as target spot or shot hole spot. Leaf spots often occur in living leaves in the late dry and wet seasons or in winter in temperate countries. There are four types of leaf spot symptoms—hard spot, false melanose, freckle spot and virulent spot (Kotzé 2000). In July 1984, *Phyllosticta* species were the cause of problems on *Muehlenbeckia adpressa* in Victoria, Australia. Virtually all mature leaves of plants contained distinctive necrotic spots for an area of 10 sq. m. Spots were roughly circular to elliptical in shape and were tan with a maroon margin (Paul and Blackburn 1986). Freckle disease occurs on several species and varieties of banana (Fig. 1d). Characteristic spots (pycnidia and ascomata) form on fruit, giving the lesion a sandpaper texture. Leaves of banana will turn yellow when infected with this fungus (Wulandari et al. 2010).

Phyllosticta species as endophytes

Endophytes are fungi that asymptotically colonize plant tissues during some phase of their life cycle (Petriani 1991; Hyde and Soyong 2008; Saikkonen 2007), but may turn pathogenic during host senescence (Rodriguez and Redman 2008; Rodriguez et al. 2009). The relationship may be symbiotic, antagonistic, neutral or mutualistic (Hyde and Soyong 2008; Aly et al. 2011). Endophytes are horizontally transmitted, and transfer to their host plants via airborne spores. However, some endophytes may also be vertically transmitted to the next host plant generations via seeds (Hartley and Gange 2009). Although the first discovery of endophytes dates already back to 1904, they did not receive considerable attention until the recent recognition of their pharmaceutical and ecological significance (Gunatilaka 2006). Recent development of screening technologies revealed the great potential of endophytes as a major source of biologically active compounds (Strobel and

Table 2 *Phyllosticta* species recorded as endophytes in selected studies

Species	Host	Country	Plant organ	Reference
<i>P. bifrenariae</i>	Orchidaceae	Brazil	Leaf and bulb	Glienke et al. (2011)
<i>P. brazilianiae</i>	Anacardiaceae	Brazil	Leaf and fruit	Glienke et al. (2011)
<i>P. capitalensis</i>	Various hosts, woody plant	New Zealand	Leave and fruit	Baayen et al. (2002), Glienke et al. (2011)
<i>P. ilicina</i>	<i>Quercus ilex</i> (Fagaceae)	Switzerland	Leaves or needles	Collado et al. (1996)
<i>P. spinarum</i>	<i>Platyclusus orientalis</i> (Cupressaceae)	USA	Leaves	Wijeratne et al. (2008)
<i>Phyllosticta</i> sp.	<i>Ginkgo biloba</i> (Ginkgoaceae)	Japan	Leaf, petiole, twigs	Thongsandee et al. (2011)
<i>Phyllosticta</i> sp.	<i>Abies grandis</i> (Pinaceae)	USA	Leaves or needles	Carroll and Carroll (1978)

Daisy 2003; Huang et al. 2009; Xu et al. 2010; Tan and Zou 2001). Investigations related to endophytic microorganisms in plants and especially tropical hosts have increased, due to the significance of using endophytes in biological control and the discovery of biologically active compounds (Wijeratne et al. 2008; Le Calvé et al. 2011).

Although *Phyllosticta* species have been reported as endophytes there are relatively few reports of *Phyllosticta* species being recorded as endophytes in recent studies. In two volumes of the journal Fungal Diversity (Volume 41, 2010, Volume 47, 2011) there were 13 manuscripts devoted to biodiversity of fungal endophytes and only one (Lin et al. 2010) reported an endophytic *Guignardia* species. *Phyllosticta capitalensis* however has commonly been recorded as an endophyte in several studies (Baayen et al. 2002; Glienke et al. 2011, Okane et al. 2001; Okane et al. 2003) and was reported as an endophyte on more than 20 hosts in eight countries (Wulandari et al. 2010; Glienke et al. 2011). Therefore the species is thought to be one of the most common endophytic species of *Phyllosticta* (Glienke et al. 2011). There are few records of other *Phyllosticta* species recorded as endophytes and they are usually listed as unidentified *Phyllosticta* sp. (Pandey et al. 2003). Some *Phyllosticta* species reported as endophytes are listed in Table 2.

Phyllosticta species as saprobes

Most fungi have the ability to grow as saprobes, and degrade organic material from dead plant material as a food source. Plant pathogenic fungi can often survive as saprobes between growing seasons (Trigiano et al. 2004). For example, *Phyllosticta carpogena* and *P. ericae* occurred as saprobes on *Rubus* sp. (*Rosaceae*) and *Erica carnea* (*Ericaceae*), respectively (van der Aa and Vanev 2002) (Table 3).

Life cycle

Concepts concerning life cycles of plant pathogens may have significant practical consequences for plant patholo-

gists and taxonomists. Herein, we provide a schematic diagram of the life cycle of a typical species of *Phyllosticta* (*Phyllosticta ampelicida*, Fig. 2). After infection by the *Phyllosticta* or *Guignardia* propagules, pycnidia and/or ascomata develop under the leaf tissue, and produce leaf spots on the host. During the wet season conidia and ascospores, and sometimes the spermatial stage are present. Subsequently spores are released and ejected from the pycnidia and ascomata. The spores are carried by rain and wind to other leaves and young fruits. Germ tubes develop from spores and grow into leaves and develop within the plant tissue. The disease spreads by transmission by warm wind and rain during the wet season.

Secondary metabolites from species of *Phyllosticta*

Fungi are well-known as a good source of important metabolites, some of which are useful in the pharmaceutical industry and agriculture (Pearce 1997, Smith and Casey 2008, Aly et al. 2010; Xu et al. 2010; Udayanga et al. 2011). Both novel and previously known metabolites have been isolated from species of *Phyllosticta* (Tables 4, 5). Metabolites produced by *Phyllosticta* species include phyllostin and phyllostoxin. Phyllostictines A–D that were isolated from *P. cirsii* (Evidente et al. 2008b). Phytotoxins, including phyllosinol, brefeldin, and PM-toxin (Sakamura et al. 1969; Sakai et al. 1970) were extracted from *Phyllosticta maydis* (Comstock et al. 1973) and *Phyllosticta medicaginis* (Entwistle et al. 1974), respectively. Phyllostictines A–D have been tested with on five cancer cell lines which displayed growth-inhibitory activity (Le Calvé et al. 2011). In addition, five new metabolites were isolated from *P. spinarum*, reported by Wijeratne et al. (2008) namely (+)-(5S,10S)-4-hydroxymethylcyclozaronone, 3-ketotauranin, 3-hydroxytauranin, 12-hydroxytauranin, phyllospinarone.

Taxol was initially known as a phytochemical derived from the bark of *Taxus brevifolia* (Western Yew) and is an expensive and important diterpenoid anti-cancer intensive treatment drug used against breast, ovarian and lung cancers (Wani et al. 1971). It has been reported that the molecule has anti-tumour activity in several experimental

Table 3 *Phyllosticta* species recorded as saprobes in selected studies

Species	Host	Country	Plant organ	References
<i>P. acetosellae</i> A.L. Sm. & Ramsb.	<i>Rumicis acetosellae</i>	England	Leaves	Smith and Ramsbottom (1913)
<i>P. capitalensis</i>	<i>Magnolia liliifera</i>	Thailand	Senescent leaves	Okane et al. (2003)
<i>P. cocoicola</i>	Palm	Europe	Leaves	Punithalingam (1974), Taylor and Hyde (2003)
<i>P. pyrolae</i> Ellis & Everh.	<i>Pyrola rotundifolia</i>	America	Leaves	Ellis and Everhart (1889)

Table 4 Metabolites produced by *Phyllosticta* species

Compound	Properties	Name of taxa as in publication	References
Befeldin	Bioactive metabolite	<i>P. medicaginis</i>	Entwistle et al. (1974)
Phyllosinal	Bioactive metabolite	<i>Phyllosticta</i> sp., <i>P. maydis</i>	Sakamura et al.(1969), Sakai et al. (1970)
Phyllostictine	Mycoherbicide	<i>P. cirsii</i>	Evidente et al. (2008a)
Phyllostin	Anti-microbial, anti-cancer	<i>P. cirsii</i>	Evidente et al. (2008a), Le Calvé et al. (2011)
Phyllostoxin	Mycoherbicide	<i>P. cirsii</i>	Evidente et al. (2008a)
PM-toxin	Mycoherbicide	<i>P. maydis</i>	Comstock et al. (1973)
Tauranine	Anti-cancer activity	<i>P. spinarum</i>	Wijeratne et al. (2008)
Taxol	Anti-cancer activity	<i>P. tabernaemontanae</i>	Kumaran et al. (2009a)
(+)-(5S,10S)-4' hydroxymethylcyclozaronone	Inhibition of cell proliferation	<i>P. spinarum</i>	Wijeratne et al. (2008)
3-ketotauranin	Inhibition of cell proliferation	<i>P. spinarum</i>	Wijeratne et al. (2008)
3-hydroxytauranin	Inhibition of cell proliferation	<i>P. spinarum</i>	Wijeratne et al. (2008)
12-hydroxytauranin	Inhibition of cell proliferation	<i>P. spinarum</i>	Wijeratne et al. (2008)
Phyllospinarone	Inhibition of cell proliferation	<i>P. spinarum</i>	Wijeratne et al. (2008)

trials. Taxol is produced by various fungal strains of *Pestalotiopsis* (Strobel et al. 1996, 1997), *Phomopsis* (Kumaran and Hur 2009) and *Phyllosticta* (Kumaran et al. 2008a, b, 2009a) in culture media under various conditions. Taxol has been reported from *P. citricarpa*, from *Citrus medica* and *P. dioscoreae* from *Hibiscus rosa-sinensis* (Kumaran et al. 2008a, 2009b). Species of *Phyllosticta* are therefore potential sources for discovery of pharmaceutical, medical and agricultural novel compounds.

Phyllosticta in biocontrol

Biocontrol is “the control of unwanted organisms such as weeds by the use of other organisms, as through the use of organisms that are natural predators, parasites, or pathogens (<http://www.answers.com/topic/biological-pest-control#ixzz1YSqa0e00>)” Fungi are commonly used as biological control agents (Charudattan and Dinoor 2000, Mortensen 1998; Trujillo 2005; Roskopf et al. 2000). *Phyllosticta* species may have potential for use as biocontrol agents although there are presently few examples (Table 5). A strain of *Phyllosticta* (Ph511) was shown to produce compounds

that had high affect on motility of the second stage juveniles of *Meloidogyne incognita* and has potential in parasitic nematode control (Yan et al. 2011). *P. cirsii*, a pathogen isolated from diseased leaves of *Cirsium arvense* has been evaluated as a potential biocontrol agent of this noxious perennial weed, also produces different phytotoxic metabolites with potential herbicidal activity when grown in liquid cultures (Evidente et al. 2008a). The metabolites reported are Phyllostictines A–D which are potential mycoherbicides (Berestetskiy et al. 2008; Evidente et al. 2008a,b).

Need for epitypification of *Phyllosticta* species

An epitype is a fresh specimen (usually with accompanying culture) selected to serve as a representative type when such authentic material has been recollected, and confirmed to represent the same species as the original type material (Phillips et al. 2006; Hyde et al. 2010a, b; Abd-Elsalam et al. 2010). This practice enables mycologists to link older names to DNA data derived from fresh collections. The sole purpose of epitypification, is to move mycology into the culture and DNA era. When an epitype is designated the original material

Table 5 *Phyllosticta* species used in biocontrol

Species	Host	Compound name	Used against	References
<i>Phyllosticta cirsii</i>	<i>Cirsium arvense</i>	Phyllostictine A–D	<i>Cirsium arvense</i> (weed)	Evidente et al. (2008b)
<i>Phyllosticta</i> sp.	<i>Cirsium arvense</i>	Phyllostin (8-hydroxy-3-methyl-2-oxo-2,3,4a, 5,8,8a-hexahydrobenzo[1,4]dioxine-6-carboxylic acid methyl ester)	<i>Cirsium arvense</i>	Tuzi et al. (2010)
<i>Phyllosticta</i> sp.	<i>Curcumis sativus</i>	Ph511	<i>Meloidogyne incognita</i> root knot nematode	Yan et al. (2011)

that the epitype supports must be explicitly cited. Several authors have discussed the urgent need for epitypification in plant pathogenic genera (Verkley et al. 2004; Crous 2005; Crous et al. 2007; Shenoy et al. 2007; Hyde et al. 2010a, b; Cai et al. 2011). Since few species of *Phyllosticta* have been epityped or have ex-type cultures available it is imperative that pathogenic species are recollected and epitypified as has been done for other plant pathogenic genera.

Notes on selected species of *Phyllosticta*

Molecular data has to date proven to be inadequate in resolving many species in the genus *Phyllosticta* (Wulandari et al. 2009). Either there are very few species of *Phyllosticta* with some having a very wide host range, or the genes that we are presently using do not resolve species complexes. Differentiation of the 192 species accepted by van der Aa (1973) and van der Aa and Vanev (2002) was based on morphological data with often minor differences, and molecular evidence is not available to support this differentiation. Most species also lack living cultures and their uniqueness cannot be confirmed. For this reason it is not possible to list which species can be stated as currently in use in *Phyllosticta*, as has been done for *Cochliobolus* (Manamgoda et al. 2011), *Colletotrichum* (Hyde et al. 2009), *Fusarium* (Summerell et al. 2010; Summerell and Leslie 2011) and *Phomopsis* (Udayanga et al. 2011).

Below we discuss alphabetically selected *Phyllosticta* names which includes the generic type, an earlier name for the generic type, plant pathogens and endophytes resolved using molecular data, all taxa introduced since van der Aa and Vanev (2002) and some other taxa that we believe warrant discussion and is partly based on the most recent literature. This cannot be considered as a thorough account of the generic species, but provides a starting point towards establishing the number of acceptable species in future revisionary treatments of *Phyllosticta* as phylogenetic data accumulates and helps to resolve the species.

The account of selected species names provides authorities and publication details as appeared in *Index Fungorum* (<http://www.indexfungorum.org/names/Names.asp>). Synonyms are not given as these can be searched for in *Index Fungorum*. The teleomorph is given where known. This is not a rigorous list as it is impossible to verify at this stage whether collections of each taxon on a host are correctly identified. We have annotated the notes with host range, symptoms and known distribution, and additional notes on pathological, taxonomic and phylogenetic research. Also the additional notes emphasize the need for molecular data in future studies. We recommend that other resolved species are added to this selected list based on future studies of *Phyllosticta* employing molecular and morphological data as has been done in *Colletotrichum* (Phoulivong 2011).

When referring to *Phyllosticta* species one also has to consider the teleomorph *Guignardia*. However, although there is molecular data for this teleomorphic genus, it is mostly for the endophyte incorrectly identified as *G. mangiferae* (e.g. *P. capitalensis*). We therefore do not discuss *Guignardia* species below. However, *Guignardia psidii* Ullasa & Rawal, was shown to be distinct in the molecular analysis of Wang et al. (2011). This strain (CBS 100250) was isolated from a fruit of *Psidium guajava* collected from Sao Paulo, Brazil. The *Phyllosticta* state is unknown. Several new species of *Guignardia* have also been described in recent years (e.g. *G. musicola* N.F. Wulandari, L. Cai & K.D Hyde, *G. bispora* N.F. Wulandari & K.D. Hyde, Wulandari et al. 2010, 2011) and these also need recollecting and sequencing to establish their relationships with species of *Phyllosticta* and whether they can be considered as distinct species.

Phyllosticta ampelicida (Engelm.) Aa, Stud. Mycol. 5: 28 (1973)

Teleomorph: *Guignardia bidwellii* (Ellis) Viala & Ravaz, Bull. Soc. mycol. Fr. 8:63 (1892)

Hosts: *Vitis* spp., *Ampelopsis* spp., *Cissus* spp., *Parthenocissus* spp. (*Vitaceae*).

Disease symptoms: Black rot

Distribution: Asia, Canada, South America, UK and USA.

Notes: This *Phyllosticta* species is linked to the generic type of *Guignardia* and has a *Leptodothiorella* spermatial state. The black rot fungus can infect all parts of the vine, although the most significant losses are caused by berry infection (Reddick 1911, Miller 1968; Kuo and Hoch 1996; Wilcox 2003; Ellis et al. 2004). In warm humid climates, susceptible varieties can experience complete loss if the pathogen is left uncontrolled (Hoover et al. 2011). Sequences of reference isolates of this species are available in GenBank but it has not yet been epitypified.

Phyllosticta ardisiicola Motohashi, I. Araki & C. Nakash., Mycoscience 49 (2008)

Hosts: *Ardisia crenata* (*Myrsinaceae*)

Disease symptoms: Leaf spot

Distribution: Japan

Note: This species was introduced as new species based on its morphological differences with taxa from related hosts (Motohashi et al. 2008). Molecular data should be included in future work to confirm the status with closely related species.

Phyllosticta aspidiicola Motohashi, I. Araki & C. Nakash., Mycoscience 49: 138–146 (2008)

Hosts: *Aspidistra elatior* (*Liliaceae*)

Disease symptoms: Leaf spot

Distribution: Japan

Note: This species were introduced as new species base on its morphological differences with taxa from related hosts (Motohashi et al. 2008). Molecular data should be included in future work to confirm the status with closely related species.

Phyllosticta beaumarisii A.P. Paul & M.D. Blackburn, Australas. Pl. Path. 15: 41 (1986)

Spermatial state: *Leptodothiorella* sp.

Hosts: *Muehlenbeckia adpressa* (Nyctaginaceae)

Disease symptoms: leaf spots with distinctive necrotic lesions

Distribution: Australia

Note: The disease is prevalent during autumn and winter. Mature diseased leaves age and abscise when a new flush of growth occurs in spring. Pathogenicity testing has shown that *P. beaumarisii* is the causal agent of the disease as compared to other species of *Phyllosticta* associated with the host (Paul and Blackburn 1986). Although Yip (1987) have provided the full description and illustration of the species, molecular data is needed in future studies to confirm its status as distinct species.

Phyllosticta bifrenariae O.L. Pereira, C. Glienke & Crous, Persoonia 26: 52 (2011)

Hosts: *Bifrenaria harrissoniae* (Orchidaceae)

Disease symptoms: Leaf spot

Distribution: Brazil

Notes: This isolate was originally thought to be representative of *P. capitalensis* but was found to be ecologically and phylogenetically distinct and a pathogen of *Bifrenaria harrissoniae* (Glienke et al. 2011).

Phyllosticta brazilianiae D. Stringari, C. Glingke & Crous, Persoonia 26: 47–56 (2011)

Hosts: *Mangifera indica* (Anacardiaceae)

Disease symptoms: Symptomless endophyte

Distribution: Brazil

Note: The species is ecologically distinct from *P. anacardiacearum* being an endophyte, and failing to induce leaf spots despite repeated inoculation on mango (Glienke et al. 2011). Molecular data has also shown that it is distinct from other closely related species.

Phyllosticta capitalensis Henn., Hedwigia 48: 13 (1908)

Hosts: *Phyllosticta capitalensis* was originally described on *Stanhopea* (Orchidaceae) from Brazil by Hennings (1908) although now thought to occur in wide range of hosts.

Disease symptoms: leaf spots (when cause disease)

Distribution: Worldwide

Note: *Phyllosticta capitalensis* is the most recently proposed name for the entities that were formally incorrectly referred to as *Guignardia mangiferae* (Baayen et al. 2002; Glienke et al. 2011). The taxon is frequently isolated as an endophyte and has a wide host range and geographic distribution. Okane et al. (2001) identified an endophytic *Phyllosticta* strain in ericaceous plants from Japan, as *Phyllosticta capitalensis*, describing the teleomorph as a new species, *G. endophyllicola*. Baayen et al. (2002) recognized the common endophytic species associated with a wide host range of plants based on ITS sequence

similarities, which was similar to *G. endophyllicola* in morphology. Although several names were available for this species, they opted to call the species *G. mangiferae* (a pathogen on *Mangifera indica* (Anacardiaceae) in India), while the anamorph was referred to as *P. capitalensis*. Although no clear argument was presented for choosing the name *G. mangiferae* for this fungus, the choice of the anamorph name was based on the fact that two isolates from *Orchidaceae* (CBS 398.80, CBS 226.77) clustered in the same clade in their study. A comprehensive study of endophytic and pathogenic *Phyllosticta* species on *Citrus* was carried out by Glienke et al. (2011). Their combined phylogenetic tree revealed the *P. capitalensis sensu lato* clade to be genetically distinct from a reference isolate of *G. mangiferae* isolated from India. Several names were available for this clade, the oldest being *P. capitalensis*. Glienke et al. (2011) therefore, suggested that endophytic, non-pathogenic isolates occurring on a wide host range would be more correctly referred to as *P. capitalensis*. However, more genes need to be analyzed to fully resolve the morphological variation still observed within this clade.

Phyllosticta citriasiana Wulandari, Crous & Gruyter, Fungal Diversity 34: 31 (2009).

Hosts: *Citrus maxima* (Rutaceae)

Disease symptoms: tan spots (produces shallow lesions with a small central grey to tan crater usually with dark brown margin on fruits)

Distribution: Asia (China, Thailand, Vietnam)

Notes: The tan spot symptom usually appears after the fruit has started to ripen and sometimes it can occur after harvest. Combined gene analysis, morphological and culture based characters were employed to distinguish the species from *P. citricarpa* and other species considered (Wulandari et al. 2009). Recent studies on endophytic and pathogenic species of *Phyllosticta* from citrus in different regions of the world shows that the morphological, cultural and biochemical characters for species were consistent with the results of phylogenetic analysis of related taxa (Glienke et al. 2011; Wang et al. 2011). A specific primer pair Pca8/ITS4 was also designed and selected, and a PCR protocol was used to detect *P. citriasiana* in recent study (Wang et al. 2011).

Phyllosticta citribraziliensis C. Glienke & Crous, Persoonia 26: 54 (2011)

Hosts: *Citrus limon* (Rutaceae)

Disease symptoms: Symptomless endophyte

Distribution: Brazil

Notes: This species is closely related to *P. spinarum* but phylogenetically distinct. Also *P. citribraziliensis* is morphologically distinguished in having larger conidia, a thick mucilaginous sheath surrounding its conidia and branched conidiophores.

Phyllosticta citricarpa (McAlpine) van der Aa, Stud. Mycol. 5: 40 (1973)

Teleomorph: *Guignardia citricarpa* Kiely

Hosts: *Citrus aurantium*, *C. limon*, *C. delicoisa*, *C. reticulata*, *C. sinensis* (*Rutaceae*)

Disease symptoms: Black spot of citrus, foliar and fruit diseases, premature fruit drop

Distribution: Asia, Africa, Australia, USA (Florida)

Notes: *P. citricarpa* causes foliar and fruit disease of *Citrus* spp. *G. citricarpa* (anamorph *P. citricarpa*) which causes Citrus Black Spot is regulated as a quarantine pest in the European Union and the USA (Wang et al. 2011). This pathogen can infect the rind of Citrus fruit causing disease lesions (Kiely 1948a). Serious infection near the pedicel of the developing fruit possibly will lead to premature fruit drop (Baayen et al. 2002). The first report of Black spot on Citrus orchards was near Sydney, Australia and it was described as *Phoma citricarpa* McAlpine (McAlpine 1899). The teleomorph was described as *Guignardia citricarpa* Kiely (Kiely 1948b). van der Aa (1973) classified the anamorph as *Phyllosticta citricarpa* (McAlpine) Van der Aa. The species was recollected from Australia and an epitype was designated and the distinctiveness from *P. citriasiatica* was confirmed (Glienke et al. 2011).

Phyllosticta citrichinaensis H.X. Wang, K.D. Hyde & H.Y. Li, Fungal Diversity (2011)

Hosts: Citrus spp. (*Rutaceae*)

Distribution: China

Disease symptoms: small grey, red-brown or brown spots and freckles on leaves, melanose like black spots on fruits

Notes: This taxon has been isolated as an endophyte and is also weak pathogen (Wang et al. 2011). *P. citrichinaensis* differs from the other four *Phyllosticta* species associated with citrus in its morphological, cultural and biochemical characteristics.

Phyllosticta convallariae Pers., Traité sur les Champignons Comestibles (Paris): 148 (1818)

Hosts: *Polygonatum* spp., *Convallaria* (*Convallariaceae*), *Maianthemum* (*Liliaceae*).

Disease symptoms: Red leaf spot

Distribution: Asia, Europe

Note: This is the generic type of *Phyllosticta* and has been clearly designated in Donk (1968). This species causes reddish-brown leaf spots on its host and has a *Leptodothiorella* spermatial state (<http://www.uni-graz.at/~oberma/fungi-of-austria/phylllosticta-convallariae.html>; available online 19 Sep, 2011) and needs recollected and epitypifying. An earlier name was found in *Phyllosticta cruenta* (van der Aa 1973) but this needs confirmation based on sequencing collections from the original host.

Phyllosticta cruenta (Fr.) J.J. Kickx, Fl. Crypt. Flandres 1: 412 (1867)

Teleomorph: *Guignardia reticulata* (DC.: Fr.) Aa

Hosts: *Polygonatum* spp., *Convallaria* (*Convallariaceae*), *Maianthemum* (*Liliaceae*).

Disease symptoms: Leaf spot

Distribution: Asia, Europe

Notes: *P. cruenta* is the earlier name for type of *Phyllosticta convallariae* and in older literature, it was considered to be an intermediate form between *Phyllostictina* and *Dothiorella* (van der Aa and Vanev 2002). This taxon should be recollected and epitypified as its distinctiveness from *P. convallariae* needs confirmation.

Phyllosticta cussoniae Cejp, Bothalia 10(2): 341 (1971)

Teleomorph: *Guignardia cussonia* Crous

Host: *Cussonia* spp.

Disease symptoms: On leaves causing a prominent leaf spot.

Distribution: South Africa

Notes: In the phylogenetic tree presented in Glienke et al. (2011) the isolates of this species clusters in a distinct clade and appears to represent a distinct taxa. Representative isolates were obtained from South Africa by P.W. Crous and designated as epitype (Glienke et al. in prep.).

Phyllosticta dioscoreae Cooke, Grevillea 6(no. 40): 136 (1878)

Teleomorph: *Guignardia dioscoreae* A.K. Pande, Sydowia 22(5–6): 367 (1969) [1968]

Host: *Dioscorea* spp. (*Dioscoreaceae*)

Disease symptoms: Leaf spot

Distribution: Africa (South Africa), Asia, Australia, South America (Brazil), USA.

Notes: An isolate identified as *Phyllosticta dioscoreae* from *Hibiscus rosa-sinensis* has been reported to produce the anti-cancer compound taxol (Kumaran et al. 2009b), but the species was identified on basis of morphological characters and therefore needs confirmation with molecular data. This species commonly causes leaf spots on *Dioscorea* spp. with its *Guignardia* state usually being produced (N. Wulandari, pers. comm.) and should be recollected and epitypified to establish if it is a distinct species.

Phyllosticta fallopiae Motohashi, I. Araki & C. Nakash., Mycoscience 49 (2008)

Hosts: *Fallopia japonica*

Disease symptoms: leaf spots

Distribution: Japan

Note: This species were introduced as new species base on its morphological differences with taxa from related hosts therefore molecular data are needed in future studies to establish its uniqueness (Motohashi et al. 2008).

Phyllosticta hypoglossi (Mont.) Allesch., Rabenh. Krypt.-Fl., Edn 2 (Leipzig) 1(6): 163 (1898)

Hosts: Living leaves and dead cladodes *Ruscus* spp. (*Liliaceae*)

Disease symptoms: Occurring on living and dead cladodes and stems, though distinct spots not reported,

Distribution: Asia, Europe (France, Italy, Portugal, Turkey, Ukraine)

Notes: The spermatial state is a *Leptodothiorella* sp. The taxon was originally described from France, and the sequenced isolates used by Glienke et al. (2011) collected from Italy could potentially be used for epitypification.

Phyllosticta kerriae Motohashi, I. Araki & C. Nakash., Mycoscience 49 (2008)

Teleomorph: Unknown

Hosts: *Kerria japonica*

Disease symptoms: leaf spots

Distribution: Japan

Note: This species were introduced as new species base on its morphological differences with taxa from related hosts therefore the molecular based re evaluation is needed to establish its uniqueness (Motohashi et al. 2008).

Phyllosticta minima (Berk. & M.A. Curtis) Underw. & Earle, Bulletin of the Alabama Agricultural Experiment Station 80: 168 (1897)

Hosts: *Acer* spp. (Maples) (*Sapindaceae*)

Disease symptoms: Leaf spot (black or purple eye spot).

Distribution: Asia (China), North America

Notes: This pathogen has been reported as a common causative agent of ornamental *Acer* spp. (<http://www.unce.unr.edu/publications/files/ho/2005/fs0547.pdf>). *Phyllosticta gallarum* has been recorded causing similar leaf spots on *Caragana* spp. (<http://www.unl.edu/nac/diseasetrees/chap4.pdf>). Recollection and taxonomic re evaluation is needed to confirm if this species can be differentiated from closely related species.

Phyllosticta musarum (Cooke) Aa, *Stud. Mycol.* 5: 72 (1973)

Teleomorph: *Guignardia musae* Racib.

Hosts: *Musa* spp. (*Musaceae*).

Disease symptoms: Leaf spot, fruit spot, banana freckle, banana black spot

Distribution: Widespread

Notes: The pathogen (*Phyllosticta musarum* or the sexual state *Guignardia*) infects leaves and also affects the external appearance of the fruit, decreasing its quality and marketability. Severe infections of the disease may cause premature death of the older leaves on some banana cultivars. Preinfection studies shows that the pathogen seems to penetrate directly through the epidermal cuticle layer of the host by forming appressoria and infection pegs (Pu et al. 2008). Wulandari et al. (2010) investigated the problem of the occurrence of the species epithet (“musae”) on separate occasions related to sexual state based on herbarium specimens and fresh collectios and distinguished there different species including taxonomic novelties. However the *Phyllosticta/Guidnardia* species from banana

needs to re evaluated based on morphological and molecular approach in future studies.

Phyllosticta owaniana G. Winter, *Hedwigia* 24: 31 (1885)

Host: *Brabejum stellatifolium* (*Proteaceae*)

Disease symptoms: leaf spot

Distribution: South Africa

Notes: *P. telopeae* Yip has been reported from *Telopea speciosissima* (*Proteaceae*) and is distinguished from *P. owaniana* by its larger conidia and much longer appendages. Both of the species being accepted in van der Aa and Vanev (2002). The sequences of the type of *P. owaniana* has been used in phylogenetic analysis but as the outgroup which shows the species to be significantly different from other *Phyllosticta* species. An epitype will be designated based on fresh collections (Glienke et al., in prep).

Phyllosticta solitaria Ellis & Everh., *Proc. Acad. nat. Sci. Philad.* 47: 430 (1895)

Hosts: *Malus* spp., *Crataegus* spp. (*Rosaceae*). *Pyrus* spp.

Disease symptoms: Leaf spot, fruit blotch, twig canker.

Distribution: Asia (India, China), Africa (Zimbabwe, South Africa), Europe (Greece), North America (USA), South America (Brazil).

Notes: Although the teleomorph is unknown, Guba (1925) have noticed the fructification on fallen leaves in spring (van der Aa and Vanev 2002). *P. solitaria* causes a serious blotching of apples which reduces fruit quality and also known as quarantine pest by EPPO (http://www.eppo.org/QUARANTINE/fungi/Phyllosticta_solitaria/PHYSSL_ds.pdf). The ability of the fungus to withstand long periods of cold storage should be noted in quarantine purposes. Re-evaluation of the pathogen and epitypification is needed in future studies.

Phyllosticta sphaeropsoides Ellis & Everh., *Bull. Torrey bot. Club* 10(7): 97 (1883)

Teleomorph: *Guignardia aesculi* (Peck) V.B. Stewart

Hosts: *Aesculus* spp. (*Hippocastanaceae*).

Disease symptoms: leaf blotch (disease known as buckeye blotch or horse chestnut blotch), black rot, brown leaf margin and necrotic tissue

Distribution: Asia, Europe, North America

Notes: *Guignardia aesculi* (sexual stage), initiates leaf infections in early spring, while *P. sphaeropsoides* (asexual stage) perpetuates infections during the summer. Infections from both stages combine to cause horse chestnut leaf blotch (Gillman 2005; Pastricakova 2004). Recollection from various host species of *Aesculus* and various geographical locations are needed to establish the uniqueness of the taxa with molecular data.

Phyllosticta spinarum (Died.) Nag Raj & M. Morelet, *Bull. Soc. Sci. nat. Arch. Toulon et du Var* 34(219): 12 (1978)

Hosts: *Juniperus* sp., *Chamaecyparis pisifera*, *Platyclusus orientalis* (Cupressaceae), *Hedera helix* (Araliaceae)

Disease symptoms: none reported, presumed endophyte

Distribution: Europe (Germany, France, Italy), USA

Notes: This was originally described from *Juniperus* sp. in Germany while the isolates sequenced in Glienke et al. (2011) were from *Chamaecyparis pisifera* and *Hedera helix* (from France and Italy). The endophytic isolate putatively identified as *P. spinarum* from *Platyclusus orientalis* is known to produce novel secondary metabolites (Wijeratne et al. 2008).

Phyllosticta vaccinii Earle, Bull. Torrey bot. Club 24: 31 (1897)

Teleomorph: *Guignardia vaccinii* Shear

Hosts: *Vaccinium* spp. (Ericaceae).

Disease symptoms: Blast or blight of flowers and young fruits; early rot of fruits in storage

Distribution: Asia (China), North America

Notes: Weidemann et al. (1982) listed the anamorph of *Guignardia vaccinii* as *Phyllosticta elongata*, but van der Aa (2002) lists both *Phyllosticta elongata* and *Phyllosticta vaccinii* as anamorphs. A strain of this species (CBS165.86) has been sequenced by Duong (2008) and appears to be a distinct species in phylogenetic analysis. However, future work is needed to establish the uniqueness of taxa.

Concluding remarks

Species recognition criteria in *Phyllosticta* and the sexual state *Guignardia* have evolved from morphological criteria to phylogenetic species concepts that involves DNA sequence data derived from type material. However as compared to the number of accepted species in previous revisionary treatments, there is a lack of molecular-based studies considering the wide range of hosts and various geographic locations. We therefore recommend the recollection of taxa, and epitypification where possible. The number of resolved names in the genus would be updated with ongoing projects and the sexual states should be linked accordingly to establish operational biological species.

Acknowledgements We acknowledge The Royal Golden Ph.D. Jubilee Program grant No. Ph.D./0198/2552 in 2.B.M.F./52/A.1.N.XX for the first author to carry out a PhD on the taxonomy and phylogeny of the genus *Phyllosticta*. Dhanushka Udayanga thanks Chinese Academy of Sciences, Beijing and Mushroom Research Foundation, Thailand for a postgraduate scholarship. The National Research Council of Thailand awarded grant No 54201020004 to study the genus *Phyllosticta* in Thailand. The Global Research Network for Fungal Biology and King Saud University are also thanked for support.

References

- Abd-Elsalam KA, Yassin MA, Moslem MA, Bahkali AH, de Wit PJGM, McKenzie EHC, Stephenson S, Cai L, Hyde KD (2010) Culture collections are becoming the herbaria for fungal pathogens. *Fungal Divers* 45:21–32
- Aly AH, Debbab A, Kjer J, Proksch P (2010) Fungal endophytes from higher plants: a prolific source of phytochemicals and other bioactive natural. *Fungal Divers* 41:1–16
- Aly AH, Debbab A, Proksch P (2011) Fungal endophytes: unique plant inhabitants with great promises. *Appl Microbiol Biotechnol* 90:1–17
- Aveskamp MM, De Gruyter J, Crous PW (2008) Biology and recent developments in the systematics of *Phoma*, a complex genus of major quarantine significance. *Fungal Divers* 31:1–18
- Aveskamp M, De Gruyter J, Woudenberg J, Verkley G, Crous PW (2010) Highlights of the Didymellaceae: a polyphasic approach to characterise *Phoma* and related pleosporalean genera. *Stud Mycol* 65(1):1–60
- Baayen R, Bonants P, Verkley G, Carroll G, Van Der Aa H, De Weerd M, van Brouwershaven I, Schutte G, Maccheroni W Jr, de Blanco C (2002) Nonpathogenic isolates of the citrus black spot fungus, *Guignardia citricarpa*, identified as a cosmopolitan endophyte of woody plants, *G. mangiferae* (*Phyllosticta capitalensis*). *Phytopathology* 92(5):464–477
- Berbee ML, Taylor JW (2001) Fungal molecular evolution: gene trees and geological time. In: McLaughlin DJ, McLaughlin EG, Lemke PA (eds) *The mycota*, vol. 7B, systematics and evolution. Springer, New York, pp 229–245
- Berestetskiy A, Dmitriev A, Mitina G, Lisker I, Andolfi A, Evidente A (2008) Nonenolides and cytochalasins with phytotoxic activity against *Cirsium arvense* and *Sonchus arvensis*: a structure–activity relationships study. *Phytochemistry* 69(4):953–960
- Cai L, Hyde KD, Taylor PWJ, Weir B, Waller J, Abang MM, Zhang JZ, Yang YL, Phoulivong S, Liu ZY, Prihastuti H, Shivas RG, McKenzie EHC, Johnston PR (2009) A polyphasic approach for studying *Colletotrichum*. *Fungal Divers* 39:183–204
- Cai L, Udayanga D, Manamgoda DS, Maharachhikumbura SSN, McKenzie EHC, Guo LD, Liu XZ, Bahkali AH, Hyde KD (2011) The need to carry out reinventory of tropical plant pathogens. *Trop Plant Pathol* (In press)
- Carroll GC, Carroll FE (1978) Studies on the incidence of coniferous needle endophytes in the Pacific Northwest. *Can J Bot* 56:3034–3043
- Charudattan R, Dinooor A (2000) Biological control of weeds using plant pathogens: accomplishments and limitations. *Crop Prot* 19:691–695
- Collado J, Platas G, Peláez F (1996) Fungal endophytes in leaves, twigs and bark of *Quercus ilex* from Central Spain. *Nova Hedwigia* 63(3):347–360
- Comstock J, Martinson C, Gengenbach B (1973) Host specificity of a toxin from *Phyllosticta maydis* for Texas Cytoplasmically Male–Sterile Maize. *Phytopathology* 63:1357–1361
- Crouch JA, Beirn LA (2009) Anthracnose of cereals and grasses. *Fungal Divers* 39:19–44
- Crouch JA, Clarke BB, Hillman BI (2009) What is the value of ITS sequence data in *Colletotrichum* systematics and species diagnosis? A case study using the falcate–spored graminicolous *Colletotrichum* group. *Mycologia* 101(5):648–656
- Crous PW (2005) Impact of molecular phylogenetics on the taxonomy and diagnostics of fungi. *Bull OEPP/EPPD* 35:47–51
- Crous PW, Slippers B, Wingfield MJ, Rheeder J, Marasas WFO, Philips AJ, Alves A, Burgess T, Barber P, Groenewald JZ (2006) Phylogenetic lineages in the Botryosphaeriaceae. *Stud Mycol* 55:235–253

- Crous PW, Braun U, Groenewald JZ (2007) *Mycosphaerella* is polyphyletic. *Stud Mycol* 58:1–32
- Crous PW, Groenewald JZ (2005) Hosts, species and genotypes: opinions versus data. *Australas Plant Pathol* 34(4):463–470
- de Gruyter J, Woudenberg JH, Aveskamp MM, Verkley GJ, Groenewald JZ, Crous PW (2010) Systematic reappraisal of species in *Phoma* section *Paraphoma*, *Pyrenochaeta* and *Pleurophoma*. *Mycologia* 102(5):1066–1081
- Desmazieres MJBHJ (1847) Quatorzieme notice sur les plantes cryptogames recemment decouvertes en france. *Ann Sci Nat Bot Ser* 3(8):9–37
- Donk MA (1968) Report of the committee for Fungi and Lichen 1964–1968. *Taxon* 17:578–581
- Duong ML (2008) Fungal diversity on leaf litter of five selected tree species in Chiang Mai Province, Thailand. PhD Thesis, Chiang Mai University
- Ellis JB, Everhart BM (1889) New and rare species of North American fungi (Sphaeropsidae). *J Mycol* 5(3):145–157
- Ellis M, Doohan D, Bordelon B, Welty C, Williams R, Funt R, Brown M (2004) Midwest Small Fruit Pest Management Handbook. The Ohio State University Extension. 123–125 http://ohioline.osu.edu/b861/pdf/ch05_123-125.pdf. Accessed 19 October 2011
- Entwistle ID, Howard CC, Johnstone RAW (1974) Isolation of brefeldin A from *Phyllosticta medicaginis*. *Phytochemistry* 13(1):173–174
- Evidente A, Cimmino A, Andolfi A, Vurro M, Zonno M, Motta A (2008a) Phyllostoxin and phyllostin, bioactive metabolites produced by *Phyllosticta cirsii*, a potential mycoherbicide for *Cirsium arvense* biocontrol. *J Agric Food Chem* 56(3):884–888
- Evidente A, Cimmino A, Andolfi A, Vurro M, Zonno MC, Cantrell CL, Motta A (2008b) Phyllostictines A–D, oxazatricycloalkenones produced by *Phyllosticta cirsii*, a potential mycoherbicide for *Cirsium arvense* biocontrol. *Tetrahedron* 64(8):1612–1619
- Gillman HD (2005) Plant Pathologist. UMass Extension Landscape, Nursery & Urban Forestry Program Fall http://www.umassgreeninfo.org/fact_sheets/diseases/guignardia_leaf_blotch.pdf. Accessed 19 October 2011
- Glienke C, Pereira O, Stringari D, Fabris J, Kava-Cordeiro V, Galliterasawa L, Cunnington J, Shivas R, Groenewald J, Crous PW (2011) Endophytic and pathogenic *Phyllosticta* species, with reference to those associated with Citrus Black Spot. *Persoonia* 26(1):47–56
- Guba EF (1925) *Phyllosticta* leaf spot, fruit blotch and canker of the apple: Its etiology and control. University of Illinois Agricultural Experiment Station
- Gunatilaka AAL (2006) Natural Products from plant-associated microorganisms: distribution, structural diversity, bioactivity, and implications of their occurrence. *J Nat Prod* 69(3):509–526
- Hartley SE, Gange AC (2009) Impacts of plant symbiotic fungi on insect herbivores: mutualism in a multitrophic context. *Annu Rev Entomol* 54:323–342
- Hawksworth DL (2004) Fungal diversity and its implications for genetic resource collections. *Stud Mycol* 50:9–18
- Hawksworth DL (2011) Naming *Aspergillus* species: progress towards one name for each species. *Med Mycol* (In press)
- Hennings PC (1908) Fungi S. Paulenses IV. a cl. Puttemans collecti. *Hedwigia* 48:1–20
- Hoover E, Wold-Burkness S, Hilton J, Mollov D, Burkness E, Galvan T, Hemstad P, Hutchison WD (2011) Grape IPM Guide for Minnesota Producers. http://pdc.umn.edu/prod/groups/cfans/@pub/@cfans/@pdc/documents/asset/cfans_asset_175589.pdf. Accessed 19 October 2011
- Huang WY, Cai YZ, Surveswaran S, Hyde KD, Corke H, Sun M (2009) Molecular phylogenetic identification of endophytic fungi isolated from three *Artemisia* species. *Fungal Divers* 36:69–88
- Hudson H (1987) *Guignardia* leaf blotch of horsechestnut. *Trans Br Mycol Soc* 89(3):400–401
- Hyde KD (1995) Fungi from palms. XX. The genus *Guignardia*. *Sydowia* 47:180–198
- Hyde KD, Soyong K (2008) The fungal endophyte dilemma. *Fungal Divers* 33:163–173
- Hyde KD, Cai L, Cannon PF, Crouch JA, Crous PW, Damm U, Goodwin PH, Chen H, Johnston PR, Jones EBG, Liu ZY, McKenzie EHC, Moriwaki J, Noireung P, Pennycook SR, Pfenning LH, Prihastuti H, Sato T, Shivas RG, Taylor PWJ, Tan YP, Weir BS, Yang YL, Zhang JZ (2009) *Colletotrichum*—names in current use. *Fungal Divers* 39:147–182
- Hyde KD, Abd-Elsalam K, Cai L (2010a) Morphology: still essential in a molecular world. *Mycotaxon* 114(1):439–451
- Hyde KD, Chomnunti P, Crous PW, Groenewald JZ, Damm U, Koko TW, Shivas RG, Summerell BA, Tan YP (2010b) A case for re-inventory of Australia's plant pathogens. *Persoonia* 25:50–60
- Hyde KD, McKenzie E, KoKo TW (2011) Towards incorporating anamorphic fungi in a natural classification—checklist and notes for 2010. *Mycosphere* 2:1–88
- Kickx J (1849) Recherches pour servir a la flore cryptogamie des Flandres, Cent. *Mem Acad R Sci Lett Arts Belg* 4:1–59
- Kiely T (1948a) *Guignardia citricarpa* n. sp. and its relationship to the black spot disease of Citrus in coastal orchards of New South Wales. *J Aust Inst Agr Sci* 14(2):81–83
- Kiely TB (1948b) Preliminary studies on *Guignardia citricarpa* n. sp.: the ascigerous stage of *Phoma citricarpa* McAlp. and its relation to black spot of Citrus. *Proc Linn Soc NSW* 73:249–292
- Kirk PM, Cannon PF, Minter DW, Stalpers JA (2008) *Ainsworth and Bisby's dictionary of the fungi*, 10th edn. CAB International, Wallingford
- Kotzé JM (2000) Compendium of citrus diseases. In: Whiteside JO, Garsney SM, Timmer LW (eds) *Black spot*. The American Phytopathological Society Press, St Paul, pp 23–25
- Kumaran RS, Hur BK (2009) Screening of species of the endophytic fungus *Phomopsis* for the production of the anticancer drug taxol. *Biotechnol Appl Biochem* 54(1):21–30
- Kumaran RS, Muthumary J, Hur B (2008a) Production of Taxol from *Phyllosticta spinarum*, an endophytic fungus of *Cupressus* sp. *Eng Life Sci* 8(4):438–446
- Kumaran RS, Muthumary J, Hur BK (2008b) Taxol from *Phyllosticta citricarpa*, a leaf spot fungus of the angiosperm *Citrus medica*. *J Biosci Biotech* 106(1):103–106
- Kumaran RS, Muthumary J, Hur BK (2009a) Isolation and identification of an anticancer drug, taxol from *Phyllosticta tabernaemontanae*, a leaf spot fungus of an angiosperm, *Wrightia tinctoria*. *J Microbiol* 47(1):40–49
- Kumaran RS, Muthumary J, Kim E-K, Hur B-K (2009b) Production of taxol from *Phyllosticta dioscoreae*, a leaf spot fungus isolated from *Hibiscus rosa-sinensis*. *Biotechnol Bioproc Eng* 14(1):76–83
- Kuo KC, Hoch HC (1996) The parasitic relationship between *Phyllosticta ampellicida* and *Vitis vinifera*. *Mycologia* 88(4):626–634
- Le Calvé B, Lallemand B, Perrone C, Lenglet G, Depauw S, Van Goietsenoven G, Bury M, Vurro M, Herphelin F, Andolfi A (2011) In vitro anticancer activity, toxicity and structure–activity relationships of phyllostictine A, a natural oxazatricycloalkenone produced by the fungus *Phyllosticta cirsii*. *Toxicol Appl Pharmacol* 254:8–17
- Lin X, Huang YJ, Zheng ZH, Su WJ, Qian XM, Shen YM (2010) Endophytes from the pharmaceutical plant, *Annona squamosa*: isolation, bioactivity, identification and diversity of its polyketide synthase gene. *Fungal Divers* 41:41–51

- Liu K, Ding X, Deng B, Chen W (2009) Isolation and characterization of endophytic taxol-producing fungi from *Taxus chinensis*. *J Ind Microbiol Biotechnol* 36:1171–1177
- Liu AR, Chen SC, Wu SY, Xu T, Guo LD, Jeewon R, Wei JG (2010) Cultural studies coupled with DNA based sequence analyses and its implication on pigmentation as a phylogenetic marker in *Pestalotiopsis* taxonomy. *Mol Phylogenet Evol* 57(2):528–535
- Maharachchikumbura SSN, Guo LD, Chukeatirote E, Bahkali AH, Hyde KD (2011) *Pestalotiopsis*—morphology, phylogeny, biochemistry and diversity. *Fungal Divers* 50:167–187. doi:10.1007/s13225-011-0125-x
- Manamgoda DS, Cai L, Bahkali AH, Chukeatirote E, Hyde KD (2011) *Cochliobolus*: an overview and current status of species. *Fungal Divers*. doi:10.1007/s13225-011-0139-4
- McAlpine D (1899) Fungus diseases of citrus trees in Australia, and their treatment. RS Brain, Government Printer
- McManus PS (1998) First report of early rot of cranberry caused by *Phyllosticta vaccinii* in Wisconsin. *Plant Dis* 82(3):350–350
- McNeil J, Barrie FR, Burdet HM, Demoulin V, Hawksworth DJ, Marhold K, Nicolson DH, Prado J, Silva PC, Skog JE, Wiersma JH, Turlane NJ (2006) International Code of Botanical Nomenclature (Vienna Code) adopted by the Seventh International Botanical Congress Vienna, Australia, July 2005. ARG Gantner Verlag, Ruggel, Liechtenstein:1–568
- Miller JW (1968) Black rot of Grape. *Plant Pathology Circular* 76. <http://www.freshfromflorida.com/pi/enpp/pathology/pathcirc/pp76.pdf>. Accessed 19 October 2011
- Mortensen K (1998) Biological control of weeds using microorganisms. In: Boland GJ, Kuykendall LD (eds) Plant–microbe interactions and biological control. Marcel Dekker Inc., New York, pp 223–248
- Motohashi K, Araki I, Nakashima C (2008) Four new species of *Phyllosticta*, one new species of *Pseudocercospora*, and one new combination in *Passalora* from Japan. *Mycoscience* 49(2):138–146
- Motohashi K, Inaba S, Anzai K, Takamatsu S, Nakashima C (2009) Phylogenetic analyses of Japanese species of *Phyllosticta sensu stricto*. *Mycoscience* 50(4):291–302
- Okane I, Nakagiri A, Ito T (2001) Identity of *Guignardia* sp. inhabiting ericaceous plants. *Can J Bot* 79(1):101–109
- Okane I, Lumyong S, Nakagiri A, Ito T (2003) Extensive host range of an endophytic fungus, *Guignardia endophyllicola* (anamorph: *Phyllosticta capitalensis*). *Mycoscience* 44(5):353–363
- Olatinwo RO, Hanson EJ, Schilder AMC (2003) A first assessment of the cranberry fruit rot complex in Michigan. *Plant Dis* 87:550–556
- Page RDM (1996) Tree View: an application to display phylogenetic trees on personal computers. *Comput Appl Biosci* 12(4):357–358
- Pandey AK, Reddy MS, Suryanarayanan TS (2003) ITS–RFLP and ITS sequence analysis of a foliar endophytic *Phyllosticta* from different tropical trees. *Mycol Res* 107(4):439–444
- Pastricakova K (2004) *Guignardia aesculi* (Peck) Stewart—Fungal pathogen on aesculus leaves in Slovakia. *acta fytotechnica et zootechnica*, Vol. 7, Special Number, Proceedings of the XVI. Slovak and Czech Plant Protection Conference organised at Slovak Agricultural University in Nitra, Slovakia
- Paul A, Blackburn M (1986) *Phyllosticta beaumarisii* sp. nov.: a cause of leafspot on *Muehlenbeckia adpressa*. *Aust Plant Pathol* 15(2):40–41
- Paul I, Van Jaarsveld A, Korsten L, Hattingh V (2005) The potential global geographical distribution of Citrus Black Spot caused by *Guignardia citricarpa* (Kiely): likelihood of disease establishment in the European Union. *Crop Prot* 24(4):297–308
- Pearce C (1997) Biologically active fungal metabolites. *Adv Appl Microbiol* 44:1–80
- Persoon CH (1818) *Traite sur les champignons comestibles, contenant l'undication des especes nuisible precede d'une introduction a l'histoire des Champignons–Paris*
- Petrak F, Sydow H (1927) Die Gattungen der Pyrenomyzeten, Sphaeropsidn und Melanconieen. I. Die Phacospen Sphaeropsiden und die Gattung *Macrophoma*. *Reprum Spec nov Regni veget Beih* 42:1–551
- Petrini O (1991) Fungal endophytic of tree leaves. In: Andrews J, Hirano SS (eds) *Microbial ecology of leaves*. Springer Verlag, pp 179–197
- Phillips AJL, Oudemans P, Correia A, Alves A (2006) Characterisation and epitypification of *Botryosphaeria corticis*, the cause of blueberry cane canker. *Fungal Divers* 21:141–155
- Phillips AJL, Alves A, Pennycook SR, Johnston PR, Ramaley A, Akulov A, Crous PW (2008) Resolving the phylogenetic and taxonomic status of dark-spored teleomorph genera in the *Botryosphaeriaceae*. *Persoonia* 21:29–55
- Phoulivong S (2011) *Colletotrichum*, naming, control, resistance, biocontrol of weeds and current challenges. *Curr Res Environ Appl Mycol* 1(1):53–73
- Pu J, Xie Y, Zhang X, Qi Y, Zhang C, Liu X (2008) Preinfection behaviour of *Phyllosticta musarum* on banana leaves. *Aust Plant Pathol* 37(1):60–64
- Punithalingam E (1974) Studies on Spheropsidales in culture II. *Mycol Pap* 136:1–63
- Reddick D (1911) The black-rot disease of grapes. *Cornell iversity Agric Exp Station Bull* 293:287–364
- Rodrigues KF, Sieber TN (2004) Characterization of *Guignardia mangiferae* isolated from tropical plants based on morphology, ISSR–PCR amplifications and ITS1–5.8 S–ITS2 sequences. *Mycol Res* 108(1):45–52
- Rodriguez R, Redman R (2008) More than 400 million years of evolution and some plants still can't make it on their own: plant stress tolerance via fungal symbiosis. *J Exp Bot* 59(5):1109–1114
- Rodriguez R, White J Jr, Arnold A, Redman R (2009) Fungal endophytes: diversity and functional roles. *New Phytol* 182(2):314–330
- Roskopf EN, Charudattan R, DeValerio JT, Stall WM (2000) Field evaluation of *Phomopsis amaranthicola*, a biological control agent of *Amaranthus* spp. *Plant Dis* 84:1225–1230
- Rossman AY, Palm-Hernández ME (2008) Systematics of plant pathogenic fungi: why it matters. *Plant Dis* 92(10):1376–1386
- Saikkonen K (2007) Forest structure and fungal endophytes. *Fungal Biol Rev* 21(2–3):67–74
- Sakai R, Sato R, Niki H, Sakamura S (1970) Biological activity of phyllostinol, a phytotoxic compound isolated from a culture filtrate of *Phyllosticta* sp. *Plant Cell Physiol* 11(6):907–920
- Sakamura S, Niki H, Obata Y, Sakai R, Matsumoto T (1969) Isolation and structure of phytotoxic compounds produced by *Phyllosticta* sp. *Agric Biol Chem* 33(5):698–703
- Santos J, Phillips A (2009) Resolving the complex of *Diaporthe* (*Phomopsis*) species occurring on *Foeniculum vulgare* in Portugal. *Fungal Divers* 34:111–125
- Seifert KA, Rossman AY (2010) How to describe a new fungal species. *IMA Fungus* 1:109–116
- Shenoy BD, Jeewon R, Hyde KD (2007) Impact of DNA sequence-data on the taxonomy of anamorphic fungi. *Fungal Divers* 26(1):1–54
- Shenoy BD, Jeewon R, Wang H, Amandeep K, Ho WH, Bhat DJ, Crous PW, Hyde KD (2010) Sequence data reveals phylogenetic affinities of fungal anamorphs *Bahusutrabejia*, *Diplococcium*, *Natarajania*, *Paliphora*, *Polyschema*, *Rattania* and *Spadicoides*. *Fungal Divers* 44:161–169

- Silva M, Pereira O, Braga I, Lelis S (2008) Leaf and pseudobulb diseases on *Bifrenaria harrisoniae* (Orchidaceae) caused by *Phyllosticta capitalensis* in Brazil. *Australas Plant Dis Notes* 3(1):53–56
- Smith SA, Casey WD (2008) Phyutility: a phyloinformatics tool for trees, alignment and molecular data. *Bioinformatics* 24(5):715–716
- Smith AL, Ramsbottom J (1913) New or rare microfungi. *Trans Br Mycol Soc* 4:165–185
- Strobel G, Daisy B (2003) Bioprospecting for microbial endophyte and their natural products. *Microbiol Mol Biol Rev* 67:491–502
- Strobel G, Yang X, Sears J, Kramer R, Sidhu RS, Hess W (1996) Taxol from *Pestalotiopsis microspora*, an endophytic fungus of *Taxus wallachiana*. *Microbiology* 142(2):435–440
- Strobel GA, Hess W, Li JY, Ford E, Sidhu RS, Sears J, Summerell B (1997) *Pestalotiopsis guepinii* a taxol-producing endophyte of the wollemi pine, *Wollemia nobilis*. *Aust J Bot* 45(6):1073–1082
- Summerell BA, Leslie JF (2011) Fifty years of *Fusarium*: how could nine species have ever been enough? *Fungal Divers* 50:135–144
- Summerell BA, Laurence MH, Liew ECY, Leslie JF (2010) Biogeography and phylogeography of *Fusarium*: a review. *Fungal Divers* 44:3–13
- Swofford D (2002) Sinauer Associates; Sunderland, MA: 2002. PAUP* Phylogenetic analysis using parsimony (* and other methods), version 4
- Sydow H (1926) *Fungi in itinere Costaricensi collecti. Pars secunda.* *Annals Mycol* 24(5–6):283–426
- Tan R, Zou W (2001) Endophytes: a rich source of functional metabolites. *Nat Prod Rep* 18(4):448–459
- Taylor JE, Hyde KD (2003) Microfungi of tropical and temperate palms. *Fungal Divers Res Ser* 12:1–459
- Thongsandee W, Matsuda Y, Ito S (2011) Temporal variations in endophytic fungal assemblages of *Ginkgo biloba* L. *J For Res.* doi:10.1007/s10310-011-0292-3
- Trigiano RN, Windham MT, Windham AS (2004) *Plant pathology: concepts and laboratory exercises.* CRC Pr I Llc
- Trujillo EE (2005) History and success of plant pathogens for biological control of introduced weeds in Hawaii. *Biol Control* 33:113–122
- Tuzi A, Andolfi A, Cimmino A, Evidente A (2010) X-Ray Crystal structure of phyllostin, a metabolite produced by *Phyllosticta cirsii*, a potential mycoherbicide of *Cirsium arvense*. *J Chem Crystallogr* 40:15–18
- Uchida JY, Aragaki M (1980) Nomenclature, pathogenicity, and conidial germination of *Phyllostictina pyriformis*. *Plant Dis* 64:786–788
- Udayanga D, Liu XX, McKenzie EHC, Chukeatirote E, Bahkali AH, Hyde KD (2011) The genus *Phomopsis*: biology, applications, species concepts and names of common phytopathogens. *Fungal Divers* 50:189–225
- van der Aa HA (1973) Studies in *Phyllosticta* I. *Stud Mycol* 5:1–110
- van der Aa HA, Vanev S (2002) A revision of the species described in *Phyllosticta*. CBS, Utrecht
- Verkley GJM, Crous PW, Groenewald JZ, Burun U, Aptroot A (2004) *Mycosphaerella punctiformis* revisited: morphology, phylogeny, and epityfication of the type species of the genus *Mycosphaerella* (Dothideales, Ascomycota). *Mycol Res* 108:127–1282
- Wang X, Chen G, Huang F, Lou J, Hyde KD, Li H (2011) *Phyllosticta* species associated with citrus disease in China. *Fungal Divers* 51. doi:10.1007/s13225-011-0140-y
- Wani MC, Taylor HL, Wall ME, Coggon P, McPhail AT (1971) Plant antitumor agents. VI. Isolation and structure of taxol, a novel antileukemic and antitumor agent from *Taxus brevifolia*. *J Am Chem Soc* 93(9):2325–2327
- Weidemann G, Boone D, Burdsall H Jr (1982) Taxonomy of *Phyllosticta vaccinii* (Coelomycetes) and a new name for the true anamorph of *Botryosphaeria vaccinii* (Dothideales, Dothioraceae). *Mycologia* 74:59–65
- Wijeratne EMK, Paranagama PA, Marron MT, Gunatilaka MK, Arnold AE, Gunatilaka AAL (2008) Sesquiterpene quinones and related metabolites from *Phyllosticta spinarum*, a fungal strain endophytic in *Platyclusus orientalis* of the Sonoran Desert (1). *J Nat Prod* 71(2):218–222
- Wilcox WF (2003) Black rot *Guignardia bidwellii* (Ellis) Viala and Ravaz. Disease Identification Sheet No. 102GFSG-D4. Cornell Cooperative Extension. http://www.nysipm.cornell.edu/factsheets/grapes/diseases/grape_br.pdf. Accessed 19 October 2011)
- Wulandari N, To-Anun C, Hyde KD, Duong L, De Gruyter J, Meffert J, Groenewald J, Crous PW (2009) *Phyllosticta citriasiana* sp. nov., the cause of Citrus tan spot of *Citrus maxima* in Asia. *Fungal Divers* 34:23–39
- Wulandari NF, To-Anun C, Lei C, Abd-Elsalam KA, Hyde KD (2010) *Guignardia/Phyllosticta* species on banana. *Cryptogam Mycol* 31(4):403–418
- Wulandari N, To-Anun C, McKenzie E, Hyde KD (2011) *Guignardia bispora* and *G. ellipsoidea* spp. nov. and other *Guignardia* species from palms (Arecaceae). *Mycosphere* 2(2):115–128
- Xu J, Ebada SS, Proksch P (2010) *Pestalotiopsis* a highly creative genus: chemistry and bioactivity of secondary metabolites. *Fungal Divers* 44:15–31
- Yan X, Sikora RA, Zheng J (2011) Potential use of cucumber (*Cucumis sativus* L.) endophytic fungi as seed treatment agents against root-knot nematode *Meloidogyne incognita*. *J Zhejiang Univ Sci B* 12(3):219–225
- Yip HY (1987) *Phyllosticta tortilicaudata* sp. nov. on *Atherosperma moschatum* in Australia and further notes on *Phyllosticta beaumarisii*. *Aust Plant Pathol* 16(3):59–65