Current status of knowledge of Sri Lankan mycota

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The Sri Lankan mycota is inadequately described, although there are a number of studies on its biodiversity. Current estimates suggest that there could be as many as 25,000 species, of which only a little more than 2,000 are presently known, and this estimate does not take into account the large number of exotics introduced with food, plantation, and ornamental plants. In addition, only limited parts of the island have been explored. The available information is widely dispersed, difficult to access, and plagued by synonymy. This paper describes the current status of Sri Lankan Mycology, and makes suggestions for facilitating further research.

Key words – biodiversity – lichens – microfungi – mushrooms – phytopathogens – quarantine

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Introduction

Sri Lanka, though small, has a great deal of biodiversity. This is due in part to the close juxtaposition of areas widely diverse in altitude and rainfall. Sri Lanka has 2,500 years of recorded history and a prehistory of several thousand years of human habitation. During this time it has developed a cultural sensitivity to the environment and, although little of its primary forest remains, the patterns of local agriculture have left areas of floristic diversity relatively intact. Tropical and subtropical regions are potentially the richest source of new fungal species, and Sri Lanka is no exception.

Information available on Sri Lankan fungi is scattered. There are difficulties in estimating exact numbers due to synonyms used and duplicate entries. The library at the Peradeniya Botanical gardens contains the works of T. Petch and D. N. Pegler together with an extensive collection of original illustrations of agarics, but few publications of a later date. Their original collections of macrofungi, and some of microfungi however, are now located at Kew. This absence of original collections including types makes the clarification of synonymies amongst the fungi very difficult, since herbarium specimens have to be obtained from Kew, an expensive and

time consuming procedure. Because of their obvious economic importance the collections of soil fungi and plant pathogens are abundant, as is the relevant literature.

This paper will address the current status of Sri Lankan Mycology, and makes suggestions for facilitating further research.

Geography

Sri Lanka lies between latitudes 5˚ 55' and 9˚ 51' north and longitudes 79˚ 41' and 81˚ 5' east. It has an area of 65,600 square kilometers and comprises three physiogeographic units: the highlands, the midlands, and the lowlands. The highlands have an elevation of over 1,600 meters, and the midlands of between 1,600 and 300 meters; together they comprise the south central montane zone encircled by the vast lowland plains. There are also three regions demarcated by rainfall: the arid zone with an annual rainfall of 60-125 cm, the dry zone with 125-190 cm, and the wet zone with over 190 cm. The wet zone comprises the montane zone, and the western and south western lowlands. Small parts of the North West and south east belong to the arid zone whilst the rest of the lowlands make up the dry zone (Fernando 1968).

History of Sri Lankan Mycology

The first Sri Lankan fungi to be recorded were *Peziza ceylonische* and *P. lembosa* described by Houttyn in 1783. Later work by Berkeley & Broome (1870, 1871, 1873), Petch (1908a, 1908b, 1910, 1913, 1915a, 1915b, 1916a, 1916b, 1916c, 1917a, 1917b, 1919, 1922, 1923, 1924a, 1924b, 1924c, 1924d, 1925, 1926a, 1926b, 1927, 1928, 1945, 1948), and Petch and Bisby (1950) have raised the number of described species to over 2,000 in about 640 genera. T. Petch, a British mycologist worked at the Royal Botanical Gardens in Peradeniya between 1900 and 1925, also documented various plant pathogens and other fungi (Ainsworth 1976, Petch 1925).

Certain groups of fungi have been studied more intensively than others, because of their prominence (macrofungi), or practical importance (phytopathogens and mycorrhizae). The number of records in Uredinales are, *Uredo* (58 species), *Puccinia* (41 species), *Coleosporium* (3 species), *Uromyces* (19 species), *Hemileia* (1 species), *Melampsora* 4 species, *Pucciniastrum* 2 species, *Aecidium* 20 species, *Blastopota* 1 species, *Cerotelium* (1 species), *Cystospora* (1 species), *Diorchidium* (3 species), *Phragmidium* (4 species), *Ravenelia* (8 species), *Scopella* (1 species); making a total of 168 species Berkeley & Broome (1870-1877), Petch (1908-1948), and Petch & Bisby (1950). In Ustilaginales 25 species belong to 7 genera, in Exobasidiales 2 species belong to single genus.

The larger Basidiomycetes are presently the best known group in Sri Lanka, with records of 513 species of agarics in 50 genera such as *Psalliota* (*Agaricus*) 35 spp., *Pleurotus* 12 spp., *Marasmius* 53 spp., *Lentinus* 14 spp. and *Hygrophorus* 27spp. Petch & Bisby (1950); Coomaraswamy (1979, 1981a); Coomaraswamy & De Fonseka (1981b); Coomaraswamy & Kumarasingham (1988). The Herbarium of Horticultural Crop Research and Development Institute (HORDI), Gannoruwa, Peradeniya, Sri Lanka has 412 paintings of agarics by W. de Alwis, which are now available in digital form. A comprehensive Agaric Flora of Sri Lanka was published by Pegler (1986). In the 'Aphyllophorales', 342 species in 51 genera have been recorded. The dominant genera are, *Polyporus* (57 species), *Fomes/Rigidoporus* (32 species), *Poria* (23 species) and *Stereum* (26 species). Seventy five species of Gasteromycetes in 37 genera have been recorded, the dominant genera being: *Geastrum* (9 species) and *Cyathus* (4 species). In total, 1125 species in 162 genera Berkeley & Broome (1870-1877), Petch (1908-1948), and Petch & Bisby (1950). Seventy-two species of Zygomycota in 17 genera, mostly soil inhabitants, have been recorded, as have 252 Ascomycetes, mostly entomo- or phytopathogens. Only 130 species of Myxomycota in 30 genera have been recorded in Sri Lanka (Petch & Bisby 1950) and there are no records thereafter, probably due to their lack of economic importance and the absence of local expertise.

Most references to the fungi in Sri Lanka are found scattered in journals, research reports, research institutions, University proceedings and theses.

Macrofungi

There have been very few studies on the taxonomy and phylogeny of the macrofungi in Sri Lanka since Houttuyn 1783; Berkeley & Broome from 1870-1877; Petch from 1905-1925; Petch & Bisby (1950); Coomaraswamy (1979, 1981a)**;** Pegler (1986); Coomaraswamy & Kumarasingham (1988). Over 500 species of agarics have been described or recorded, mostly by M.J. Berkeley, from the collections of G. Gardner, who was the Superintendent of the Royal Botanic Gardens, Peradeniya during 1844-1849. G. H. K. Thwaites, who took an interest in the fungi helped Gardner at Peradeniya and sent over 1200 dried specimens to M. J. Berkeley at Kew, for identification. Berkeley & Broome described 403 agaric species, of which 305 provided the type collections for new species (Berkeley & Broome 1870, 1871, 1873). Based on O. Beccari's collections in 1865, Cesati (1879) described a few agaric species a few years after Berkeley and Broome's publications. F. V. Höhnel visited Sri Lanka in 1907 and rediscovered some of Berkeley & Broome specimens (Höhnel 1908, 1909, 1914). T. Petch who was appointed Mycologist at Peradeniya Royal Botanic Gardens collected mushrooms extensively on the island and published many accounts during 1905-1925. The genera *Lepiota* (Pegler 1972) and *Inocybe* (Horak 1979, 1980), and the family Entolomataceae (Pegler 1977, Horak 1980) were taken in to account concerning the recent publications of agarics. More recently *Lentinus giganteus* Berk. has been transferred to *Pleurotus* based on Thai and Sri Lankan collections (Karunarathna et al. 2011), and a new species of *Agaricus* was described from Kandy district (Karunarathna et al. 2012).

Phytopathogenic fungi in Sri Lanka

Sri Lanka has a wide diversity of crops in different agro-ecological settings (Jayawardena and Weerasena 2000). These include plantation crops: tea, rubber, and coconut; field crops: rice, legumes and maize; export crops: cloves, nutmeg, pepper, cocoa, and cardamom; timber crops: teak, jak, and mahogany; fruit trees: banana, passion fruit, and papaya; plus a diverse range of forest trees, and medicinal, fodder, and ornamental plants. Sri Lanka has a century long tradition of research into phytopathogens (Ainsworth 1976). Numerous handbooks (UNESCO: Man and the Biosphere (MAB) National Committee for Sri Lanka publications) on the fungi parasitic on plants, associated with insects, or found in soil were published in the 1970s and 1980s (Coomaraswamy 1979, 1981a; Coomaraswamy & De Fonseka 1981b; Coomaraswamy & Kumarasingham 1988). Several countrywide checklists have been published (Coomaraswamy 1979). A list of plant pathogenic fungi with host names prepared by S. Sivanathan (unpublished) is being updated.

Impact of plant pathogens, quarantine and law enforcement

There are detailed records of the serious damage caused by coffee rust (*Hemileia vastatrix*) in 1870, which defoliated the plants, and virtually ended coffee production in the Island causing the British to change their drinking habits: tea became more popular (Daniel 1993, Waller et al. 2007, Vandermeer et al. 2009). Concern about plant quarantine began in 1869, after the coffee rust disease wiped out nearly all the coffee plantations in Sri Lanka, and Indonesia banned import of both coffee and coffee sacks from Sri Lanka. This was Asia's first plant quarantine regulation (http://www.agridept.gov.lk/). In Sri Lanka, British scientists in the Department of Agriculture at Peradeniya began to quarantine plants in 1880's, and Sri Lanka became a centre for the identification of pests and diseases affecting crops, as countries in the region began sending material for identification. After the establishment of the Central Agricultural Research Institute (CARI) at Gannoruwa, Peradeniya, all plant quarantine activities were carried out there by the departments of Entomology and Plant pathology. In the early 1980's the Australian government helped establish a separate unit for Plant quarantine within the premises of CARI, and a chief Plant Quarantine officer was appointed with all responsibility for the whole island. In 1994, the present National Plant Quarantine Service complex was established at Katunayake with the help of the Japanese Government. The Plant Protection Act No.35

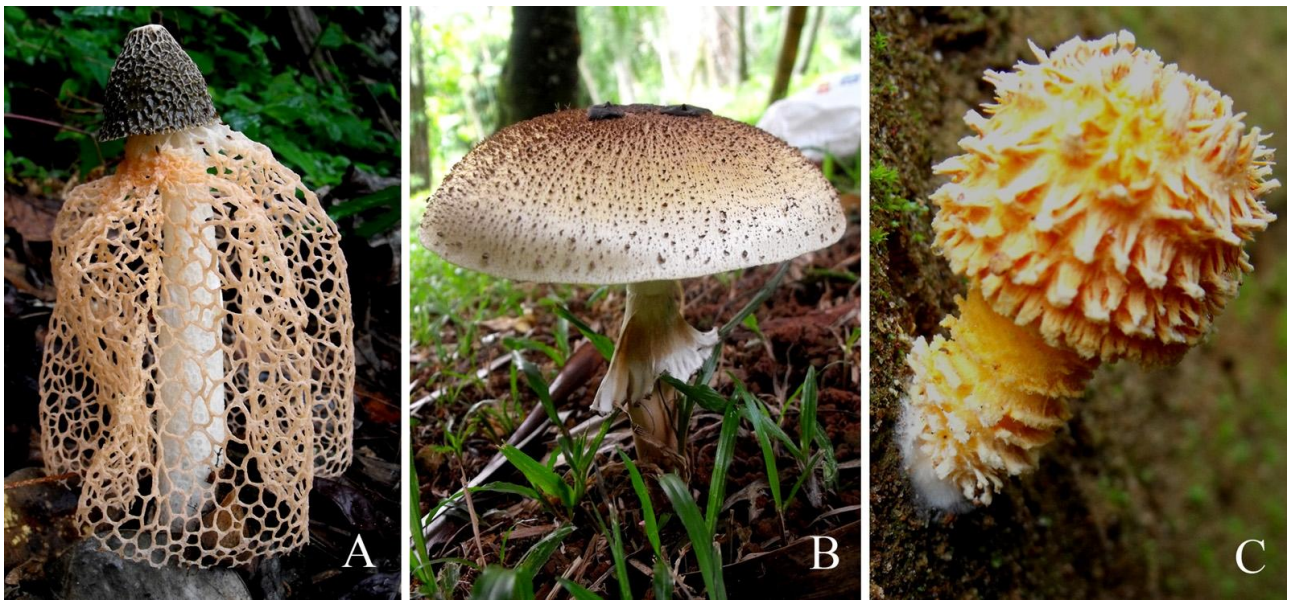

Fig. 1 – Some macrofungi observed during recent field visits in Sri Lanka **A** *Phallus indusiatus* Vent. **B** *Clarkeinda trachodes* (Berk.) Singer. **C** *Agaricus trisulphuratus* Berk. Photo credit : Samantha C. Karunarathna.

of 1999 is an approved act to make provisions against the introduction in to Sri Lanak and the spreading therein, of any organism harmful to, or injurious or destructive of plants and for the sanitation of plants in Sri Lanka (http://www.customs.gov.lk/docs).

Divisions in major research stations have been established to carry out research on the pathogens affecting the crops. They work on issues such as diversity, ecology and the management of diseases. With the rapid advance of research in fungal pathogens, the older checklists and countrywide databases such as the Diseases of cultivated plants in Ceylon by Abeygunawardhane (1969), Fungi oparasitic on the plants of Sri Lanka (Coomaraswamy 1979) quickly become outdated (Cai et al. 2011b; Ko Ko et al. 2011). Accurate identification and naming of pant pathogens provide information essential for determining the appropriate disease control measures (Rossman & Palm-Hernández 2008). It is, therefore, imperative to recollect plant pathogens, re-identify, re classify and document the up-to-date information. Table 1 summarizes the most commonly documented phytopathogenic fungi on major crops (tea, rubber, coconut, rice), based on available literature. However the lists need updating and the identifications should be confirmed in future studies.

Post harvest fungal diseases in Sri Lanka

In developing countries more than 30% of agricultural produce is lost between harvesting and consumption (Coursey & Proctor 1973, Kader 2005). Of the pathogens responsible for post-harvest loss fungi are the most important (Monica et al. 2010). Among the significant post-harvest fungal diseases of Sri Lankan fruit are: anthracnose on banana, papaya and mango (*Colletotrichum* spp.), stem end rot in banana, avocado, papaya, mango, and rambutan (*Botryodiplodia theobromae*); water blister in pineapple (*Theilaviopsis paradoxa*); green mould (*Penicilium digitatum*) and blue mould (*Penicillium italicum*) in *Citrus* fruits; and *Phytopthora* and *Phomopsis* rot in various fruits (Sivanathan & Adikaram 1989a, b; Adikaram et al. 1992; Adikaram & Karunarathne 1998; Sivakumar et al. 1997; Abayasekara et al. 1998; Karunanayake et al. 2007; Wijeratnam & Sarananda 2008). The past two decades have seen various studies on the resistance of Sri Lankan produce to post-harvest diseases, defense mechanisms and methods of control have also been studied (De Silva et al. 2005, Herath & Abeywickrama 2008). Recent surveys and reviews of tropical post-harvest pathogens have revealed an urgent need for the re-inventory of tropical pathogens, because modern molecular techniques have shown the confusion of previous studies.

Table 1 Common plant pathogen recorded in Sri Lanka on major crops (tea, rubber, coconut and rice)

Host and fungus	Disease	References
Coconut		
Bipolaris incurvata	Leaf blight disease	http://www.srilankanwebdesign.com/coconut1/
Ceratocystis paradoxa	Stem bleeding	Alfieri 1967
Ganoderma sp.	*Ganoderma* disease	http://www.srilankanwebdesign.com/coconut1/
Pestalotiopsis palmarum	Grey blight	Holliday 1995
Phytophthora palmivora	Bud Rot	http://www.srilankanwebdesign.com/coconut1/
Rice		
Alternaria padwickii	Stackburn	Seneviratne & Jeyanandarajah 2004
Cercospora janseana	Narrow brown leaf spot	Dissanayake & Wickramasinghe 1999
Cercospora janseana	Narrow brown leaf spot	Seneviratne & Jeyanandarajah 2004
Cochliobolus miyabeanus	Brown spot	Seneviratne & Jeyanandarajah 2004
Gerlachia oryzae, (*Rhynchosporium oryzae*)	Leaf scald	Seneviratne & Jeyanandarajah 2004
Gibberella fujikuroi (*Fusarium moniliforme*)	Bakanae disease	Seneviratne & Jeyanandarajah 2004
Magnaporthe grisea (*Pyricularia oryzae*)	Rice blast	Nugaliyadde et al. 2000, Seneviratne & Jeyanandarajah 2004
Magnaporthe salvinii	Stem rot	Seneviratne & Jeyanandarajah 2004
Many fungal species and bacteria	Grain spotting and pecky rice	http://www.agridept.gov.lk/index.php/en/crop-recommendations/809
Rhizoctonia solani	Sheath blight	Nugaliyadde et al. 2000
Sarocladium oryzae	Sheath rot	Nugaliyadde et al. 2000
Ustilaginoidea virens	False smut	http://www.knowledgebank.irri.org/IPM/index.php/false-smut
Rubber		
Colletotrichum acutatum	*Colletotrichum* leaf disease	Jayasinghe & Fernando 1997
Colletotrichum gloeosporioides	*Colletotrichum* leaf disease	Jayasinghe & Fernando 1997
Corynespora cassiicola	*Corynespora* leaf fall	Liyanage et al. 1986, Jayasuriya & Thennakoon 2007a
Fusarium solani	*Fusarium* wilt	Liyanage & Dantanarayana 1983
Geotrichum sp.	*Geotrichum* association on roots	Jayasinghe & Wettasinghe 1996
Nattrassia mangiferae (Neofusicoccum mangiferae)	Foot canker, sudden wilt	Jayasinghe & Silva 1994
Phytopthora spp.	Leaf fall, bark rot, shoot die-back and pod rot	Jayasuriya et al. 2007
Rigidoporus microporus	White root disease	Jayasuriya & Thennakoon 2007b
Sclerotium rolfsii	Collar rot	Jayasinghe et al. 1988
Thanatephorus cucumeris	Target leaf spot	Jayasinghe 1993
Tea		
Exobasidium vexans	Blister blight	Holliday 1995
Kretzschmaria deusta (Ustulina deusta)	Charcoal rot	Muraleedharan 2007
Macrophoma theicola	*Macrophoma* canker	Thseng et al. 2004
Nemania diffusa (Syn. Hypoxylon vestitum)	Wood decay	Balasuriya & Adikaram 2008
Phomopsis theae	Colar and branch canker	Holliday 1995
Poria hypolateritia	*Poria* root disease	Wijesundera & Kulatunga 1993
Rosellinia arcuata	Black root disease	Muraleedharan 2007

Fig. 2 – Some common fungal diseases on tea in Sri Lanka **A** Black blight caused by *Rhizoctonia solani*. **B** Blister blight caused by *Exobasidium vexans*. **C** Violet root disease caused by *Sphaerostilbe repens*. Photo credit : Tea Research Institute, Talawakelle, Sri Lanka.

(Phoulivong et al. 2010 a, b, Cai et al. 2011a, Ko Ko et al. 2011). For instance, Phoulivong et al. (2010a) compared the various *Colletotrichum* isolates from tropical fruits, and found that morphologically similar isolates from chilli, mango, papaya, rose apple and jujube may comprise more than one distinct species, which are currently poorly defined and characterized. Alahakoon et al. (1994) reported *Colletotrichum gloeosporioides* on 23 fruit crops in Sri Lanka including durian, mangosteen, pini jambu (wax apple), rambutan and 11 other less economically important fruit trees,hosts on which this pathogen had not been previously recorded. These studies have shown that fruit diseases have a considerable impact in Sri Lanka, and that a modern revisionary treatment needs to be carried out. Analysis and comparison of sequence and morphological data, followed by epitypifi-cation, will fundamentally change our understanding of these species, not only in *Colletotrichum*, but also in many other important tropical plant pathogenic genera such as *Botryosphaeria*, *Fusarium*, *Pestalotiopsis*, *Phomopsis* and *Phyllosticta* (Udayanga et al. 2011; Wikee et al. 2011; Cai et al. 2011a, b; Maharachchikumbura et al. 2011; Manamgoda et al. 2011; Liu et al. 2011). Given the economic importance of these diseases further studies are urgently needed.

Lichenological studies

G.H.K. Thwaites first collected Sri Lankan lichens in 1868. W.A. Leighton examined Thwaites' collections and identified 199 species (Leighton 1870). Almquist's collection of 1879 formed the basis of Nylander's Lichenes Ceylonenses of 1900. Eighty nine lichen species common around Kandy were recorded by A.H.G. Alston (Alston 1932). Between 1966 and 1968 S. Kurokawa and M. Mineta reported lichens mainly from the montane forests (Kurokawa and Mineta 1973), and F. Hale collected lichens in lowland rain forests during 1970's. The regional monographs of *Relicina* and *Thelotremataceae* in Sri Lanka were based upon the above collections (Hale 1980, 1981). W. Brunnbauer compiled a bibliographic description of lichens in Sri Lanka in 15 fascicles which included 550 species belonging to 122 genera and 48 families, following a botanical excursion from the University of Vienna in 1984 (Brunnbauer 1984-1987). A. H. M. Jayasooriya recorded 17 species of lichens from Ritigala (Jayasuriya 1984). C. Wijerathne described 35 new lichen species from Ritigala Mountains and its vicinity during 1999-2003. The publications of Moberg (1986, 1987), Awasthi (1991), Makhija & Patwardhan (1992), Breuss et al. (1997) and Vezda et al. (1997) increased the number of recorded lichens to 659 species. In 2009 a preliminary survey of lichens was conducted as a workshop at University of Peradeniya, and the participants collected 98 different species (Jayalal et al. 2008). N.M.C. Nayanakantha and S. Gajameragedara described about 50 lichens from Kandy municipal region in 2003 (Nayanakantha & Gajameragedara 2003, Jayalal et al. 2008). Two new additional lepraioid lichens were described by Orange (2001). A survey carried out by M.K. Karunarathna in 2006 listed 23 genera of lichens (Jayalal et al. 2008). A survey at Horton Plains National Park during 2004-2006, found 1515 specimens of macrolichens,

identified 293 species in 48 genera, four new to Sri Lanka, belonging to 13 families (Jayalal et al. 2008). In all 696 species of Sri Lankan lichens are currently reported (Jayalal et al. 2008), but ongoing research and unpublished data could raise this number to over 1500 species.

Conclusion

The identification of mushrooms, plant pathogens, and other fungi is an important part of Sri Lankan mycological research. There is an urgent need for both a national collection of fungi and a network of local working groups. It is important to have a focal point for mycological activities within the national herbarium, which would coordinate the identification and documenting of all fungi locally. The maintenance of national collection for living cultures and collaborative efforts to apply molecular based identification and updating the knowledge is also emphasized. Finally we would like to appreciate international and local mycologists for their great work on the developments Sri Lankan mycology.

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