CHAPTER 2

LITERATURE REVIEW

2.1 Ecology of fungi and their roles in ecosystem

True fungi are eukaryotic organisms, represented by their own kingdom, which is separated from plants, animals and protozoa (Deacon, 2006; James *et al*., 2006; Stephenson, 2010). They consume nutrients only by absorption (i.e. being osmotrophs) but not phagocytosis. Their cells contain flattened cristae mitochondria and a golgi apparatus; and cell walls contain chitin and β-glucans (1,3 β-, 1,6 β-glucan) (Adams, 2004). They are either unicellular or filamentous, and consist of multicellular coenocytic haploid hyphae; the diploid phase is generally short-lived. They reproduce either sexually or asexually, or both (Cavalier-Smith, 1998, 2004; Kirk *et al*., 2008).

Fungi are heterotrophic, meaning that they are not able to produce their own food in a manner similar to plants. They get their nutrients from existing organic matter from the external environment. Their hyphae can grow through and penetrate the substrates (organic compounds) on which they are feeding, and carry out extracellular digestion by secreting digestive enzymes to break down the substrates followed by nutrient absorption. Carbon sources of fungi include leaf litter, dung, soil, animals, dead wood and living plants (Hawksworth *et al*., 1996). They are predominantly terrestrial with less than two percent of known species being aquatic (Ingold, 1993).

Fungi play a range of important roles in ecosystems, among these the most well-known are being decomposers in nutrient cycling (Robinson *et al*., 1993; de Boer *et al*., 2005), mutualists to facilitate plant growth (Kendrick, 2000; Deacon, 2006), biological agents to control crop parasites (e.g. insects and nematodes [Kendrick, 2000; Deacon, 2006]), and bioindicators for air pollution (Jovan, 2008; Cabral, 2010). As decomposers fungi can also turn unwanted dead organic materials into valuable food and even biochemical compounds potentially useful for manufacturing pharmaceutical and health-care products (Alexopoulos *et al*., 1996; Hyde, 1997). However, they can cause undesirable food spoilage, biodeterioration (Alexopoulos *et al*., 1996; Dighton, 2003), and can be plant (Agrios, 2005) and animal pathogens triggering diseases (some are even fatal) of hosts and thus drawbacks in economic and social aspects (e.g. crop yield reduction, increased expenditure for curing fungal-infected patient, etc.) (Deacon, 2006; Johnson and Perfect, 2007).

Table 2.1 Ecosystem services provided by fungi (reproduced from Dighton, 2003)

	Ecosystem service	**Fungal functional group**
Soil formation	Rock dissolution	Lichens, Saprotrophs, Mycorrhizae
	Particle binding	Saprotrophs, Mycorrhizae
Providing fertility for primary production	Decomposition of organic residues	Saprotrophs (Ericoid and ectomycorrhizae)
	Nutrient mineralization	Saprotrophs (Ericoid and ectomycorrhizae)
	Soil stability (aggregates)	Saprotrophs, Arbuscular mycorrhizae
Primary production	Direct production	Lichens
	Nutrient accessibility	Mycorrhizae
	Plant yield	Mycorrhizae, Pathogens
	Defence against pathogens	Mycorrhizae, Endophytes, Saprotrophs
	Defence against herbivores	Endophytes
Plant community structure	Plant-plant interactions	Mycorrhizae, Pathogens
Secondary production	As a food source	Saprotrophs, Mycorrhizae
	Population/biomass regulation	Saprotrophs, Mycorrhizae, Pathogens
Modification of pollutants		Saprotrophs, Mycorrhizae
Carbon sequestration and storage		Mycorrhizae (Saprotrophs)

Fungi can be classified into several groups based on their development style and functional roles (Table 2.1). Individual groups have specific behaviour and they frequently interact both among themselves and with other organisms. However, this classification may be inadequate as increasing evidence has shown that fungi do not necessarily have only one niche (Zhou and Hyde, 2001). Instead, depending on environmental circumstances, they may change behaviour and development life style. Also, fungal diversity in any habitat may change over time. Some species have rapid reproduction and short life cycle whereas others have greater longevity; certain species are able to colonize new habitats quickly but are soon replaced by others. It is noteworthy that numerous species are found in limited and/or specific habitats whereas others are cosmopolitan. These variations affect their behaviour which includes their patterns of establishment on nutrient sources, their interactions with other organisms, and the types of material which they can occupy (Cooke and Rayner, 1984; Kendrick, 2000; Dix and Webster, 1995, Dighton, 2003). Substrates for fungal growth may be living or dead. Among more than 80,000 known fungal species worldwide, most are saprobic; about 100 species are pathogenic to animals and humans but more than 8000 species are plant pathogens. Plant fungi are divided into three categories according to their mode of life: endophyte, pathogen and saprobe. Certain fungi are able to switch from being endophytic or pathogenic on living plants, to being saprobic on detached and/or dead plant tissues during host senescence (Zhou and Hyde, 2001, Hyde *et al*., 2007). The fungi in this study are mostly parasites and saprobes on plant materials.

2.1.1 Endophyte

The term endophyte refers to microorganisms that colonize healthy plant tissue, causing asymptomatic infection (Wilson, 1995). Carroll (1988) and Petrini (1991) revised the definition to organisms that colonize internal plant tissues at some time in their life cycle without any direct harm to their host. This covers latent pathogens that do not cause any symptom on their host. By definition an endophyte cannot be considered disease-causing. However, the distinction between a pathogen and endophyte is not always clear (Sinclair and Cerkauskas, 1996). Some disease causing species were frequently isolated and defined as endophytes. Also, endophytic fungi may persist as saprobes once the plant organ on which they reside abscises and/or dies. Then the endophytes will grow and begin the new infection phase on the abscised plant tissue (Zhou and Hyde, 2001; Photita *et al*., 2004, 2005; Promputtha *et al*., 2005, Boddy and Griffith, 1989; Fisher and Petrini, 1992; Sridhar and Raviraja, 1995; Sieber, 2007). True fungal endophytes (i.e. not pathogens) can have a mutualistic relationship with their host. They may benefit host plants by preventing pathogenic organisms such as insect herbivores from attacking the host (Kriel *et al*., 2000), or by producing chemicals to inhibit the growth of competitors such as pathogens and unwanted weeds (Clay 1988, Carroll, 1988; Bissegger and Sieber, 1994) to help host resistance against diseases (Clay 1988, Carroll, 1988; Bissegger and Sieber, 1994; Dorwoth and Callan, 1996).

The number of fungal endophyte species infecting on a single host species can be large (Sieber, 2007; Arnold, 2007). Previous studies have shown that the diversity of fungal endophytes increases with tissue age of certain hosts (Bertoni and Cabral, 1988; Hata and Futai, 1993; Rodrigues, 1994; Brown *et al*., 1998; Taylor *et al*., 1999; Umali *et al*., 1999; Photita *et al*., 2001). This positive relationship might be due to weathering of tissue, texture, increasing exposure time to propagules, and physical changes of the plant tissue or degradation of the leaf cuticle (Petrini and Carroll, 1981; Stone, 1987; Hata and Futai, 1993).

2.1.2 Pathogens

Plant pathogenic fungi live on or in living plant host from which they remove and obtain nutrients. They invade by secreting enzymes or toxins to disintegrate the host cell components, resulting in death and degradation of host cells, and thus causing disease or reduced efficiency of host growth, development, and reproduction (Agrios, 2005; Prell and Day, 2001). Fungal pathogens can even grow on non-living substrates within living plant, resembling the saprophytic mode of nutrition (Zhou and Hyde, 2001). Later on they spread and colonize the living parts of the host.

Plant pathogenic fungi can be biotrophic or non-obligate pathogenic. Biotrophs have evolved with their host plants and developed specialized mechanisms to overcome the defence systems of host, such that they are able to attack only a narrow range of host species. For instance, biotrophs often produce specialized nutrient absorbing structures called haustoria that tap into the host tissues. Though they only have a limited number of host species, their attack and subsequent infection can seriously affect host health (Deacon, 1997, 2006). Non-obligate pathogenic fungi invade their hosts directly, and damage host tissue by producing toxins or enzymes to degrade host cells, leading to dead spots or even killing the whole leaf.

2.1.2 Saprobes

Kirk *et al*. (2008) stated that "a saprobe is an organism using dead organic material as food, and commonly causing its decay" in the Dictionary of the Fungi (10th edition). According to this definition, many fungi fall into this category. Saprobic fungi play a key role in recycling nutrients in most ecosystems. The majority grow by developing a hyphal network called a mycelium, and by using their hyphae to penetrate and invade substrates. They can degrade complex structural materials such as lignin cellulose and hemicelluloses in wood, and chitin in insect, by producing specialized decomposing enzymes. These enzymes are released from the mycelium into the substrate to digest substrate compounds, and then the hyphae again absorb nutrients through their cell wall (Deacon, 2006; de Hoog *et al*., 2000; Techa, 2001). After absorbing nutrients, saprobic fungi also release the decayed organic matter in inorganic form into the soil, making it available for other organisms. These unique mechanisms of saprobic fungi make them one of the main agents for nutrient recycling in many terrestrial and aquatic environments (Swift *et al*., 1979; Beare *et al*., 1992). Saprobic fungi include members of both Ascomycetes and Basidiomycetes. Decay of various substrates usually follows a pattern that consists of initial colonization by Ascomycetes, followed by Basidiomycetes some months later. Different fungal species and groups may produce varying types of enzymes in the degradation processes, and they also differ in organic matter uptake. Important Ascomycete genera of sabrobic fungi include *Alternaria*, *Aspergillu*s, *Chaetomium*, *Cladosporium*, *Fusarium*, *Neurospora*, *Penicillium* and *Trichoderma*, they are more efficient to grow on, and decompose a wide range of substrates, such as agricultural products, plant and animal residue, and human cadavers, than other groups of fungi

(Maren, 2002; Okoh and Tian, 2008; Rwakaikara Silver and Nkwiine, 2007; Sidrim *et al*., 2010; Song *et al*., 2010; Varga *et al*., 2000).

2.2 Fungal Taxonomy and Species Concepts

The taxonomic system based on the Linnaean hierarchical system of ranks was proposed as the key for species classification, which is mainly based upon morphological and biological characters, to which the subsequent binomial nomenclature has been adopted (Hawksworth *et al*., 1994; Lee, 2003; Ereshefsky, 2007). This system has several limitations and can be inappropriate for species classification (Pigliucci, 2003; Vasilyeva and Stephenson, 2010; Hibbett and Donoghue, 1998). For fungal taxonomy, it is also not stable which most of the revisions are the variation of names and taxonomic structure and relationships that consequently requires changes in nomenclature (Guarro *et al*., 1999; Vasilyeva and Stephenson, 2010; Shaban-Nejad and Haarslev, 2007). Traditionally, fungal taxonomy and species concepts largely focused on phenotype and their appearance (Burdsall, 1993; Shaban-Nejad and Haarslev, 2007). The main problem in traditional fungal taxonomy is that the taxonomic keys are based on defining and using “unique” morphological character states for the intended species or generic classification. However, these “unique” character states are usually subjective and the phenotypic plasticity of fungi has been highly underestimated, thus confusing the fungal phylogeny (Vasilyeva and Stephenson, 2010).

Over the past decade, application of molecular biology has developed rapidly. A variety of techniques has emerged and is now available to help mycologists understand the phylogenetic relationships of fungal species. Additionally, modern molecular methods are being used to identify cryptic species and distinguish closely related fungal taxa. Molecular techniques have proven useful in fungal taxonomy whenever morphological characters are insufficient or vague for species classification (Burdsall, 1993; Berres *et al*., 1995; Crous, 2006e).

2.2.1 Morphological Species Concept

Different species concepts have been used by mycologists to define and classify fungal species. The morphological (phenotypic) species concept is a classical approach which defines species on the basis of differential morphological and physical characteristics (Eldredge and Cracraft, 1980; Seifert 1993; Guarro *et al*., 1999; Taylor *et al*., 2000). This is appropriate for many, but not all, species as speciation may result in behavioural or genetic changes with little or no detectable change in physical characteristics. Also, phenotypic characters are affected by environmental conditions and may show high variation (Crous *et al*., 2009e). For example, fungi may be morphologically adapted to a vertical distribution on the host (Jones, 2000). Ascomycetes that occur above mean tide generally have pigmented or ornamented spores, while those found throughout the tidal range have hyaline or smoothed-walled or sheathed ascospores (Hyde, 1989). The distinction between a population and an individual is always difficult, and this can create confusion in genetic studies (Carlile and Watkinson, 1994). Many cryptic fungal species were named (and even grouped) based on only wide and/or unspecific morphological characteristics. The major problem for fungal identification is the difficulty in species recognition at higher taxonomic levels of the working with morphologically similar. This particularly occurs when these characters are highly variable and few in numbers when compared to the large number of species described (Lumbsch and Huhndorf 2007a, b).

2.2.2 Biological Species Concept

Mayr (1942) defined the biological species concept (BCS) as "Species are groups of interbreeding natural populations that are reproductively isolated from other such groups". It emphasizes gene exchange (i.e. sexual and parasexual reproduction) within species and the presence of barriers that prevent the cross-breeding of species (Davis, 1995). A species is considered to be an actual or potential interbreeding population isolated by intrinsic reproductive barriers (Avise and Ball, 1990). This seems to be true for a great number of species, but not for all species and especially not for species resulting from recent speciation. The BSC is inapplicable to organisms that do not undergo meiosis (Ghiselin 1987; Seifert *et al*., 1995) and inappropriate for species among which hybridization takes place, it is now also common in fungi (Donoghue 1985). It is also impractical for many allopatric populations in which biologists do not know whether the morphologically similar groups of organisms are able to interbreed. Application of the BSC in fungi is complicated by the difficulties in mating and in assessing its outcome (Kurtzman and Robnett, 1997). The BSC is applied only to sexual fungi, whereas asexual ones need only possess similar characteristics to each other. However in asexual fungi, genetic exchange through somatic hybridization is a theoretical possibility, although it is limited by vegetative incompatibility (Carlile and Watkinson, 1994). Also, whether a cross is considered fertile or infertile depends on the frame of current literature. In this sense, published accounts of crosses between different species are often difficult to interpret because authors have failed to specify the type of infertility and its severity (Perkins, 1994).

2.2.3 Phylogenetic Species Concept

The phylogenetic species concept (PSC) defines a species as the smallest aggregation of populations (sexual) or lineages (asexual) diagnosable by a unique combination of character states in comparable individuals (Nixon and Wheeler, 1990; Wheeler and Meier, 2000). It is commonly used to define a species as a group of organisms that share at least one uniquely derived character, perhaps with a shared pattern of ancestry and descent (Cracraft 1983) or monophyly (Donoghue, 1985; de Quieroz and Donoghue, 1988, 1990). This concept is more useful for biodiversity and conservation worth of a population than other measures (Soltis and Gitzendanner, 1999). It is also more applicable in practice than previous species concepts because it can be applied to asexual organisms and allopatric populations, and able to differentiate two or multiple species that is not achievable based on only nonphylogenetic criteria (Corbet, 1997; Cracraft, 1997; Knowlton and Weigt, 1997; Agapow *et al*., 2004). Taylor *et al*. (2000) have suggested the application of PSC for fungi because the development of new evolutionary species out of an ancestor requires changes in gene sequences before modifications in morphological traits and mating behavior.

PSC has been increasingly accepted by mycologists and has been found particularly appropriate for certain fungal groups in which no sexual reproduction has been observed (Shenoy *et al*., 2007). It is also widely used for investigating the evolution of fungal species complex based on cladistic analysis of molecular characteristics, which offers consistency in the delineation of species. Cladogram topology can detect monophyletic groups which contain either species or subspecific taxa, for example *Armillaria mellea* (Coetzee *et al*., 2000, 2003), *Collybia dryophila* (Vilgalys, 1991), *Fusarium solani* (Aoki *et al*., 2003), *Gibberella fujikuroi* (O'Donnell *et al*., 1998). Molecular data, especially DNA sequence-data, are now commonly used and have provided new information relating to the PSC. Unique DNA sequences are obtained from standardised positions in the genome and serve as a molecular diagnostic tool for species-level identification of fungi (Rossman, 2008). Because the PSC is comparatively more complicated than the MSC and the BSC, in some situations it is not easy to define the absolute differences between species (Crous, 2005). However, this problem can be avoided by the concurrent application of two- or multiple-genes genealogies (Taylor *et al*., 2000).

2.3 Fungal specificity

All plants can be attacked by at least one species or another of phytopathogenic fungi. Individual species of fungi can parasitize one or many different kinds of plants. Many fungi exhibit host specificity, indicating their dependency on a particular host species or group of related species from which they derive nutrients (Zhou and Hyde, 2001). Within the host-specific fungi, many are able to switch their nutritional modes from being endophytic or pathogenic on living plants, to being saprobic on detached/dead plant tissues during host senescence (Zhou and Hyde, 2001; Hyde *et al*., 2007).

Lucas (1998) suggested that host-specificity inferred a relationship between hosts and fungi, and has mainly been applied to plant pathogens. Plant pathogenic fungi generally able to infect living plant tissues but most pathogens differ by often showing a greater degree of host specificity (Burnett, 2003). Genetic of host specificity often appears to be determined by single or a few pairs of alleles, such as the specific virulence genes which match host resistance genes in gene-for-gene interaction (Vanderplank, 1975; Browder and Eversmeyer, 1986; van der Does and Rep, 2007).

In highly host-specific pathogens, the initial mutation or mutations conferring host specificity can be expected to be reinforced subsequently by polygenic selection, resulting in increased adaptation to the new host. Other kinds of differentiation, such as morphological changes may follow. For example, *Magnaporthe grisea* occur on graminaceous crops as host restricted races, fungal races can be interbred to give different viabilities offsprings (Murakami *et al*., 2000). Arnold *et al*. (2000, 2001) also found evidence for host preference in a study of leaf-inhabiting microfungi of two shrub species in a lowland moist tropical forest in Panama, finding 62 percent of non-singleton taxa restricted to one host or the other.

Thus far, fungi occurring on *Eucalyptus* have proven to be largely host family specific, and only a few examples are known to occur on different species or genera of *Myrtaceae*, or unrelated hosts. Presently these examples include species of *Harknessia* (Sutton and Pascoe, 1989; Crous *et al*., 1993f, 2007f; Crous and Rogers, 2001, Lee *et al*., 2004), *Cryphonectria cubensis* (Conradie et al., 1990; van Zyl *et al*., 1999; Gryzenhout *et al*., 2006b, c, 2009; Nakabonge *et al*., 2006a), *Puccinia psidii* (Coutinho *et al*., 1998), *Calonectria* (Victor *et al*., 1997, Schoch *et al*., 1999; Kang *et al*., 2001a, b; Crous, 2002; Crous *et al*., 2004e, 2006c).

2.4 Importance of fungal plant pathogens

In plant pathology, fungi are the largest group of plant pathogens with over 10,000 species shown to cause disease in crops and plants (Agrios, 2005, Sarah *et al*., 2008). Recently, fungi-like organisms such as *Pythium* and *Phytophthora* and those that cause downy mildew were previously considered fungi but because of changes in fungal taxonomy they are now classified in the kingdom Chromista (Kirk *et al*., 2008, Crous *et al*., 2009g). *Phytophthora infestans* is the causing agent of late blight of potatoes in Ireland. About 1 million people died and another 1.5 million emigrated (Alexopoulos *et al*., 1997). *Ophiostoma ulmi* caused Dutch elm disease in America and Europe. Elm trees suffered major losses, with almost total disappearance of adult trees in some areas of the world (Santini *et al*., 2003). Chestnut blight caused by *Cryphonectria parasitica* (*Endothia parasitica*) was firstly reported in 1904 on American chestnut trees in the United States. By the year 1926, the fungus was found throughout the native range of American chestnut and a major forest tree. Growth of this tree had been greatly suppressed and it was reduced to a multiple-stemmed shrub (Gravatt and Marshall, 1926). Sorghum Ergot caused by *Claviceps africana* has impacted on both seed production nurseries and grain fields of sorghum plantations worldwide (Velasquez-Valle, 1998). Fungal pathogens can cause various disease symptoms on plant host. Categories used to describe them are Anthracnose, Blight, Canker, Crown root, Damping Off, Decline, Dieback, Galls, Leaf Blotch, Leaf Curls, Leaf Spots, Mildews, Rusts, Scab, Smuts, Soft and dry root rots, Warts, Wilts and Witches' broom (Strange, 2003; Trigiano *et al*., 2004; Agrios, 2005; Cook *et al*., 2006). In the majority of cases, disease starts with necrosis of host tissue and then stunting, distortion, and abnormal changes in plant tissue and organs.

Fungi have potential physical, chemical, and biological mechanisms to parasitize the plant host. They can enter host plants through natural openings or wounds. They colonize and cause damage by producing substances that change or destroy plant tissues (Agrios, 2005; Kavanagh, 2005; Cook *et al*., 2006). They reproduce both sexually and asexually via the production of spores. These spores may be dispersed over long distances by wind, water, plant part, animals, and human activity.

According to analogies of their life cycles and parasitism, parasitic fungi can be grouped into obligate parasites, facultative saprobes, and facultative parasites. Obligate parasites only grow as a parasite on or in a living host and cannot survive as saprophytes or be cultured in the laboratory; facultative saprobes live as a parasite for most of their existence but have the ability to live on dead and decaying organic matter (being saprobic) to complete their life cycle. Most fungal pathogens are facultative saprophytes (Prell and Day, 2001), some well-known examples are *Colletotrichum lindemuthianum* which causes anthracnose of beans and *Venturia inaequalis* which causes scab in apples (Young 1927; Trigiano *et al*., 2004); Facultative parasites usually survive as a saprophyte but have the ability to parasitize and cause disease under certain conditions (Young, 1927; Trigiano *et al*., 2004), For instance, *Colletotrichum orbiculare* can grow beyond the rust lesions (induced by *Puccinia xanthii*) of *Xanthium* weeds into the surrounding tissue, then girdle the stem, and consequently kill the plant tissue (Morin *et al*., 1993).

Molecular approaches were developed due to the fact that previous approaches such as culture-based techniques and morphological studies were insufficient for plant pathogen identification. Diagnostic laboratories with fast routine protocols for molecular studies can provide reliable identification, sensitive detection, and accurate quantification of plant pathogens. In addition, they can detect and qualify multiple pathogens that have infected the plant of interest. Modern molecular technologies especially those involving polymerase chain reactions, are being developed and implemented in horticultural and agricultural practice (Lievens and Thomma, 2005).

2.5 Fungi on exotic plantations

The term "exotic" is used to describe a species introduced into a country or region from elsewhere. In contrast, species that grow naturally within the country are called "indigenous or native". Exotic plants have always occupied a prominent place in tropical forest plantation (Nair, 2001). Overall, there are more than a hundred tree species that have been introduced and established as plantations in the tropics and subtropics, with only a few dominant species.

2.5.1 Exotic fungal plant pathogens

The high productivity of exotic plantation forestry gives a lot of profits, but it is also linked to the absence of pests and pathogens in native ranges. Important diseases caused by exotic and apparently native pathogens have emerged in a number of countries (Wingfield *et al*., 2001). An emerging disease refers to a disease that has been recently found on a new host and/or a new area, or has increased in virulence (Tatiana *et al*., 2010). Increasing evidence has shown that plant pathogenic fungi are particularly responsible for new emerging diseases in plants (Anderson *et al*., 2004; Desprez-Loustau *et al*., 2007; Stukenbrock and McDonald, 2008).

2.5.2 Host shift and host jumping

Giraud *et al*. (2010) stated that "host range expansion is the evolution of the ability to exploit a novel host in addition to the host of origin" and "host shift speciation is speciation by specialisation onto a novel host". Over time, fungal pathogens may lose their parasitizing ability to their original host, so they need to infect and adapt on a new host. Diseases on a novel host were always caused by emerging fungal pathogens which previously unnoticed. They may suddenly increase in their virulence or expansion of the geographic range of a pathogen (Stukenbrock and McDonald, 2008; Fisher *et al*., 2009). Although the pathogen can be pre-adapted for infection and transmission into a new host, most successful disease emergence requires the pathogen co-adaptation (de Vienne *et al*., 2009).

Fungi may grow on dead host tissues that have been infected by other primary pathogenic species, so the coexistence of these fungi is often observed on leaf lesions and on dead organic tissue during fungal propagation and dispersal to new hosts after they have lost the connection to their original hosts (Crous *et al.*, 2008). Some fungal pathogens and saprobes can even shift to taxonomically distinct and unrelated host species within their geographical range (Roy, 2001). This contrasts with the suggestion by Ehrlich and Raven (1964) that pathogens generally colonize closely related hosts only. In order to distinguish fungi with different life styles, Roy (2001) proposed the use of "host shifting" to describe fungi that can shift among closely related hosts, and "host jumping" for fungi that can colonize taxonomically unrelated hosts. The host-changing ability can influence their genetic behavior and makeup through the processes of recombination (*Ophiostoma novo-ulmi*, Brasier 2001) and/or hybridisation (*Phytophthora* sp., Brasier *et al*., 1999; Brasier, 2000). Emergent fungal diseases associated with plant domestication are also consistent with ecological speciation by host shifts. For example, the wheat fungal pathogen *Mycosphaerella graminicola* originated in the Fertile Crescent at the time of wheat domestication (Stukenbrock *et al*., 2007), and the fungus *Rhynchosporium secalis* caused a disease called "scald" on rye, barley, and other grasses when they were first cultivated (Zaffarano *et al*., 2008).

Some presently important pathogens of *Eucalyptus* in South Africa were insignificant and had a limited range a decade ago (Wingfield *et al.*, 1989; Smith *et al*., 1994; Wingfield *et al*., 1997). The expanding area of *Eucalyptus* plantations allow fungal pathogens to cross geographical barriers to infect new hosts (i.e. from exotic *Eucalyptus* to other native trees) more easily, and also increase the chance of infection by native fungi to the exotic plantations (Slippers *et al.*, 2005c). Some examples of introduced pathogens from exotic *Eucalyptus* are *Teratosphearia cryptica*, *T. nubilosa* (Park and Keane, 1982; Wingfield *et al*., 1995; Crous *et al*., 2004c), and *T. suttonii* (Chipompha, 1987; Crous *et al.*, 1989a; Crous and Wingfield, 1997). These species were documented in Australia where *Eucalyptus* is native, but were also found later in other countries where this host has been planted as an exotic. Another important example is *Eucalyptus* rust which is caused by *Puccinia psidii* and also known as guava rust fungus (Coutinho *et al*., 1998) .This pathogen is native to Central and South America where it is found on a wide range of native Myrtaceae and it has recently infected exotic *Eucalyptus* species in South America (Dianese *et al*., 1984; Coutinho *et al*., 1998). *Puccinia psidii* now threatens exotic eucalypts (refer to the members of three closely woody plants genera: *Eucalyptus*, *Corymbia* and *Angophora*) around the world. Perhaps Australia is the origin of native Myrtaceae and contains a centre of diversity for this important plant family.

2.6 *Eucalyptus*

The plant genus *Eucalyptus* was first published in 1788 by a French botanist, Chales Louis L'Héritier de Brutelle. The specimen was collected from Bruny Island to the south of Tasmania landmass by David Nelson during Cook's third voyage to the south sea. More than fifty years after this voyage, many more species were discovered: 135 species were documented in 1867 and this number increased to over 800 in 2002 (Brooker, 2002).

Scientific classification of *Eucalyptus* L'Hér. (Govaerts *et al*., 2008)
Kingdom: Plantae
Order: Myrtales
Family: Myrtaceae
Subfamily: Myrtoideae
Tribe: Eucalypteae

The name *Eucalyptus* used to be treated as one of three similar genera which commonly mention as "eucalypts", the other two genera are *Corymbia* (Hill and Johnson, 1995) and *Angophora* Cav. (Ladiges, 1997). "Eucalypts" is derived from the Greek *eu*, "well", and *calyptos*, "covered" (Eldridge *et al*., 1993; Ladiges, 1997) which refers to the majority features in the fusion of either the petals and/or sepals to form an operculum. Morphologically, *Eucalyptus* and *Angophora* can be separated by

Angophora has flowers with free sepals and petals and not involved in operculum whereas one or two opercula which cover the numerous stamens present in *Eucalyptus* (Ladiges, 1997). Base on morphological features, Hill and Johnson (1995) treated subgenera *Blakella* and *Corymbia* had been as a genus *Corymbia* and the subgenus *Angophora* also treated as a genus. Later Brooker (2002) suggested formal taxonomy of the eucalypts, over 800 species were recognized, and they belong to 13 main evolutionary lineages. *Angophora* and *Corymbia* were treated as subgenera of *Eucalyptus*. Most species of genus *Eucalyptus* belong to the subgenus *Symphyomyrtus*, and mainly are used in forest plantations. Many molecular studies supported this classification (Sale *et al*., 1996; Ladiges and Udovicic, 2000; Udovicic and Ladiges, 2000; Steane *et al*., 2002; Ladiges *et al*. 2003; Whittock *et al*., 2003). The Hill and Johnson's classification is retained in this thesis to facilitate the discussion, treating *Angophora* and *Corymbia* as genus separate from *Eucalyptus*.

Species of *Eucalyptus* are mostly native to Australia and some islands to the north of it, only a small number are found in adjacent areas of New Guinea, Indonesia and the Philippines archipelago (Eldridge *et al*., 1993). *Eucalyptus* trees grow under a wide range of climatic and edaphic conditions in their natural habitats and have a very large gene pool which makes them suitable for planting purposes. Also, *Eucalyptus* species are fast-growing in a good form that makes them suitable for modern harvesting practices and allows an economic return within a relatively short period of time (Turnbull, 2000; Brooker, 2002). Therefore *Eucalyptus* had been successfully introduced into many countries. They are cultivated and used as fuel woods, timber, and for the paper and pulp industries throughout the tropics and subtropics including America, Europe, Africa, Mediterranean, Middle East, China, and India (Barlow, 1981; Ball, 1995).

Eucalyptus may grow in the form of a low shrub or a very large tree. It contains the tallest hardwood species in the world: *E. regnans* grows in the mountains of Victoria and Tasmania and has attained heights over 100 m (Mace, 1996). Other species such as *E. deglupta*, *E. diversicolor*, and *E. viminalis* may grow to more than 70 m (Boland *et al*., 1985). At the other extreme, some species are merely shrubs (e.g. *E. vernicosa*, Potts and Jackson 1986; *E. fructicosa*, Brooker and Kleinig, 1994). *Eucalyptus* species can exhibit large differences in form, habit, reproduction, and foliage characteristics. Most species are evergreen but some tropical species lose their leaves at the end of the dry season. The foliage may also exhibit dramatic ontogenetic changes in surface waxes, phyllotoxis, and orientation between seedling, juvenile and adult stages (Boland *et al.*, 1985; Brooker and Kleinig, 1990; Wiltshire *et al.*, 1991; Hill and Johnson, 1995).

Eucalyptus leaves usually have petiolate, pendulocus, and lance shape. Most species are concolorous (isobilateral). The truly pendulous leaf is frequently asymmetrical and oblique at the base on the underside of the vertically hanging blade. The discolourous leaf is seen prominently in the bloodwood species (e.g. *E. polycarpa*) in humid regions, in the eastern blue gums (e.g. *E. grandis*), red mahoganies (e.g. *E. pellita*), and grey gum (e.g. *E. propinqua*). *E. ckadocalyx* is strongly discolourous which occurs in dry regions of South Australia. The distinction between the two leaf types is a strong diagnostic feature. *Eucalyptus* leaves are associated with oil glands which is an important feature of the genus.

Leaf venation is also used in eucalypt identification. Generally, the midrib subtends the side veins between which are varying densities of further reticulation. The primitive pattern appears to be the strongly pinnate form in which the side veins depart the midrib at a wide angle. A great variety of patterns occurs between these extremes. In a few narrow-leaved species, the side veins are unapparent (Williams and Brooker 1997; Brooker, 2002).

Eucalyptus flowers have numerous stamens which can be in white, creamy, yellow, pink, or red in colour. The stamens are enclosed in a cap operculum composed of fused sepals or petals, or both. One important unique feature of the genus is the expansion of stamens that forces the operculum off and splitting away from the cup-like base of the flower. Flowers generally occur in clusters but can be occasionally solitary (Johnson, 1972; Pryor, 1976). The woody fruits or capsules are relatively cone-shaped and have valves at the end which open to release the seeds. Most species do not flower until adult foliage starts to appear.

The appearance of *Eucalyptus* bark, such as the manner of bark shed, the length of the bark fibres, the degree of furrowing, the thickness, and the hardness and the colour, varies with the age of the plant. Many species shed their outer bark each year but others retain the dead bark. *Eucalyptus* bark tissue increases with age.

Regular decortications occur in smooth bark while retention occurs in rough bark (Florence, 2004).

2.7 Studies of fungi on *Eucalyptus*

Eucalyptus is one of the most important tree genera in Australia growing in native forests and cultural plantations (Turnbull, 2000). It is now one of the most widely planted tree genera throughout the tropics and southern hemisphere, many species have been removed from these centre of origin to new (Wingfield, 1999; Turnbull, 2000; Wingfield *et al*., 2001a, b). With the rapid expansion of *Eucalyptus* planting, its previously unknown pathogens have been continuously discovered and the concern to fungal diseases is also growing rapidly.

2.1.1 First study

Fungi on *Eucalyptus* were first documented in Flora Tasmaniae, Hooker's Botany of the Antarctic Voyage by Berkeley (1860). They were collected from Australia as saprobes on fruits, leaves, twigs, wood, or as mycorrhizal, such as *Lentinus hepatotrichus* Berk., apud Hooker, *Lycoperdon gunnii* Berk., *Marasmius eucalypti* Berk., apud Hooker, *Octaviania archeri* Berk. (*Hydnangium archeri* (Berk.) Rodway), *Peziza ceratina* Berk. (*Phialea ceratina* [Berk.] Sacc.), *Peziza eucalypti* Berk. (*Torrendiella eucalypti* [Berk.] Spooner), *Polyporus campylus* Berk. (*Grifola campyla* [Berk.] G.H. Cunn.). The Australian foliage fungal studies were listed by Cooke (1891), while the detailed study of the pathology of *Eucalyptus* foliage diseases were started by Heather (1961a, 1965). In the past, the identification of fungi was mainly based on morphological systematics alone. Since the last decade, molecular systematics has been incorporated and proved as a useful method to help resolving the classifications of many *Eucalyptus* fungi (e.g. de Beer *et al*., 2006; Crous *et al*., 1993b; Hunter *et al*., 2006b).

2.7.2 Major Contributions

Leaf-inhabiting fungi are the most diverse group among parasitic fungi on *Eucalyptus* as described in significant research studies such as Sutton and Pascoe (1897), Handford (1956), Sutton (1971a,b, 1974, 1975, 1978), Swart (1982a, b, 1986a,b, 1988), Simpson and Cerkaukas (1996), Barber (1998), Carnegie (2007). A number of leaf-inhabiting fungal species from exotic *Eucalyptus* plantations have been documented (e.g. Hedgecock 1926; Ruperez and Munoz 1980; Dick 1982, 1990; Lanier 1986; Crous *et al*., 1989a, b; Ferreira 1989; Crous *et al*., 1990, Wingfield *et al*., 1995, Crous, 1998).

Current studies on plant-pathogenic fungi using modern techniques have allowed plant pathologists to examine important pathogen complexes such as Mycosphaerella leaf blotch (Crous, 1998, Crous *et al*., 2000a, 2001a, 2004a; Hunter *et al*., 2004), Cylindrocladium leaf blight (Crous 2002; Crous *et al*., 2004e), Cryphonectria canker (Gryzenhout *et al*., 2004), Botryosphaeria canker (Slippers *et al*., 2004a,b,c), *Phomopsis* (van Niekerk *et al*., 2005; Van Rensburg, 2006), *Quambularia* (de Beer *et al*., 2006), *Coniella* (Van Niekerk *et al*., 2004), *Cytospora* (Adams *et al*., 2005), and *Harknessia* leaf spots (Lee *et al*., 2004). These studies offered important insights for understanding fungal speciation, phylogenetic relationships, host-specificity, geographic distribution, and impact of fungal pathogens to native forests or plantations.

Table 2.2 Interesting fungi associated with *Eucalyptus*

FUNGI	PUBLICATION
Alternaria Nees	Doidge *et al*., 1953; Magnani, 1964; Gibson, 1975; Thankamma and Nair, 1989
Anthostomella Sacc.	Yip, 1989; Lu *et al*., 1999; Crous *et al*., 2006a
Ascocoma H.J. Swart (Anamorph: *Coma* Nag Raj and W.B. Kendr.)	Sutton, 1974; Swart, 1986a; Beilharz and Pascoe, 2005;
Aulographina eucalypti (Cooke and Massee) Arx and E. Müll. (Syn.: *Lembosiopsis eucalyptina* Petr. and Syd., *L. australiense* Hansf., *Lembosia eucalypti* Stevens and Dixon)	Müller and von Arx, 1962; Dick, 1982; Wall and Keane, 1984; Swart, 1988; Old and Yuan, 1994; Carnegie, 1991
Aurantiosacculus eucalypti (Cooke and Massee) Dyko and B. Sutton	Dyko *et al*., 1979
Blastacervulus eucalypti H.J. Swart	Swart, 1988

FUNGI	PUBLICATION
Botryosphaeria Ces. and De Not. and associated anomorphs	Roux *et al*., 2004b; Slippers *et al*., 2004b; Barber *et al*., 2005a; Mohali *et al*., 2007; Perez *et al*., 2010
Calonectria De Not. (Anaomorph: *Cylindrocladium* Morgan)	Crous, 2002; Crous *et al*., 2006c; Lombard *et al*., 2010c
Ceuthospora Grev.	Macauley and Thrower, 1966; Ashton and Macaulay, 1972; Swart, 1988; Crous, 1991; Crous, 1993
Clypeophysalospora latitans (Sacc.) H.J. Swart	Hansford, 1956; Mittal and Sharma, 1969; Narendra and Rao, 1977; Swart, 1988; Crous *et al*., 1990
Coniella Höhn. (Teleomorph: *Schizoparme* Shear)	Sutton, 1975, 1980; Roux and van Warmelo, 1990; van Niekerk *et al*., 2004
Coniothyrium Corda	Sutton, 1975, Swart, 1986a
Cryphonectria (Sacc.) Sacc. and D. Sacc. (Anamorph: *Endothia* Fr.)	Conradie *et al*., 1990; Myburg *et al*., 1999, 2002, 2003, 2004; Seixas *et al*., 2004; van Heerden and Wingfield, 2001; Venter *et al*., 2002; Gryzenhout *et al*., 2006b, c, 2009
Cryptosporiopsis eucalypti Sankaran and B. Sutton	Sankaran *et al*., 1995b; Booth *et al*., 2001; Old *et al*., 2002, 2003
Davisoniella eucalypti H.J. Swart	Swart, 1988
Elsinoë Racib.	Dick, 1990; Hansford, 1954; Jenkins and Bitancourt, 1955; Simpson, 1996
Fairmaniella leprosa (Fairm.) Petr. and Syd.	Dick, 1990; Crous *et al*., 1989a, 1990; Hansford, 1956; Sutton, 1971a; Swart, 1988
Hainesia lythri (Desm.) Höhn.	Lundquist and Foreman, 1986; Simpson *et al.* 1997; Sutton and Gibson, 1977; Farr *et al.* 1989; Shear and Doige, 1921
Harknessia Cooke (Teleomorphs: *Wuestneia* Auersw. ex Fuckel)	Bonar, 1928; Sutton, 1971a, 1975, 1980; Nag Raj and di Cosmo, 1981; Gálan *et al.* 1986; Sutton and Pascoe, 1989; Crous *et al.* 1993f; Crous and Rogers, 2001; Kirk *et al.* 2008, Eriksson *et al.,* 2003
Macrohilum eucalypti H.J. Swart	Swart, 1988; Dick, 1990
Microsphaeropsis Höhn.	Sutton, 1971a; Sutton, 1980; Dick, 1990; Crous and van der Linde, 1993; Bettucci and Saravay, 1993

FUNGI	PUBLICATION
Microthyrium Desm.	Dick, 1982; Swart, 1986b; Kalc, 1983
Mycosphaerella Johanson and associated anomorphs	
Ophiodothella longispora H.J. Swart	Swart, 1982b; Swart, 1988
Pachysacca Syd.	Swart, 1982b; Duncan, 1989; Dick, 1990
Phaeothyriolum Syd.	Swart, 1986b; Kalc, 1983
Phloeosporella eucalypticola H.Y. Yip	Yip, 1997
Guignardia eucalyptorum Crous (Teleomorphs: *Phyllosticta eucalyptorum* Crous, M.J.Wingf., F.A.Ferreira and Alfenas)	Crous, 1993; Crous *et al*., 1993e
Piggotia substellata Cooke	Macauley and Thrower, 1966; Ashton and Macaulay, 1972; Swart, 1988; Crous, 1991; Crous, 1993
Plectosphaera eucalypti (Cooke and Massee) H.J. Swart	Swart, 1981; Pascoe, 1990
Propolis emarginata (Cooke and Massee) Sherwood	Sherwood, 1977; Cannon and Minter, 1986; Barber, 1998
Puccinia psidii G. Winter	Ferreira, 1989; Knipscheer and Crous, 1990; Coutinho *et al*., 1998; Ferreira, 1989; Dianese *et al*., 1984, 1986; Ruiz, 1988; Ruiz *et al*., 1987
Rehmiodothis Theiss. and Syd.	Swart, 1987
Seimatosporium Corda (Syn: *Sarcostroma* Cooke)	Swart, 1982a, 1988; Swart and Williamson, 1983; Crous *et al*., 1995a
Selenophoma Maire	
Staninwardia B. Sutton	Sutton, 1971b
Stilbospora foliorum Cooke	Swart, 1988
Thyriopsis sphaerospora Marasas	Marasas, 1966; Lundquist and Baxter, 1985; Cémara and Dianese, 1993
Vermisporium H.J. Swart and M.A. Will.	Swart, 1982a, 1988; Swart and Williamson, 1983; Hansford, 1956; Crous *et al*. 1990; Nag Raj, 1993

2.7.3 Biodiversity of fungi on *Eucalyptus*

Eucalyptus appears to host an incredibly diverse range of microfungi (Sankaran *et al*., 1995a; Crous *et al*., 2006d, 2007f; Summerell *et al*., 2006; Cheewandkoon *et al*., 2009) in which a large proportion have not been described and studied. The high diversity of *Eucalyptus* species was also thought to relate to high biodiversity of associated fungi (May and Simpson, 1997). May and Simpson (1997) used the estimated ratio of number of fungal species to vascular plant host, which was suggested being approximately 10:1 (Harksworth, 1991), to estimate the number of fungal species on *Eucalyptus*. If the number of *Eucalyptus* species is more than 700, there should be at least 7000 species of fungi hosted by them.

Studies on fungal diversity on *Eucalyptus* have received the attention of mycologists. Many different groups of fungi have been studied, such as saprobic fungi (e.g. Crous *et al*., 2006f, 2007f; Gryzenhout *et al*., 2006b; Summerell *et al*., 2006), plant pathogenic fungi (e.g. Crous *et al*., 1989b, 1998b, 2000b; Heather, 1961; Gryzenhout *et al*., 2004) and endophyte (e.g. Bettucci and Saravay,1993; Bettucci *et al*., 1999; Perez *et al*., 2010; Smith *et al*., 1996b). However, the understanding of fungal diversity and specificity is still poor.

2.7.4 Selected important fungi on *Eucalyptus*

Eucalyptus is one of the most important tree genera in Australia growing as native forest tree and cultural plantation (Turnbull *et al*., 2000). It is now one of the most widely planted tree genera throughout the world in the tropics and Southern Hemisphere, many species have been removed from these centre of origin to new (Wingfield, 1999; Wingfield *et al*., 2001a, b; Turnbull, 2000). With the rapid expansion of *Eucalyptus* planting, many new leaf pathogens have been discovered and interest in the pathology of leaf diseases of eucalypts has increased. There are several examples of major fungal leaf pathogens in *Eucalyptus* plantations which can severely limit the productivity of *Eucalyptus* grown in their centre of origin and exotic plantations.

Coniella Höhn. (Teleomorph: _Schizoparme_ Shear)

Coniella leaf spot and blight were found on *Eucalyptus* species in plantations and nurseries (Park *et al*., 2000). They were particularly abundant on *Eucalyptus* growing under excessively humid conditions (Park *et al*., 2000) and were commonly encountered in the surveys. The telemorph of *Coniella* Höhn is *Schizoparm*e (Castlebury *et al*., 2002; van Niekerk *et al*., 2004). *Coniella* is single-celled, relatively ellipsoidal with obtuse apices and a truncate base, and becomes dark brown at maturity. Its pycnidia are globose and dark brown to black, and are embedded in the lesions, sometimes concentrically arranged and extrude vast numbers of conidia onto the lesion surface. Disease symptoms can vary depending on fungal species, host species, plant age, and the severity of the infestation (Sutton, 1980; Old *et al*., 2003). The disease can cause circular yellow-brown spots which begin from the leaf margin or leaf tips and spread to form large blights, with small black fruiting bodies visible on the upper surface (Park *et al*., 2000). Severely infested leaves can be completely covered by these blights and are discarded prematurely (Griffiths *et al*., 2004). Up till now six species of *Coniella* have been recorded on *Eucalyptus* and they can be differentiated by conidial size and shape (Sutton, 1980; Park *et al*., 2000; Old *et al*., 2003; van Niekerk *et al*., 2004). *Coniella* species appear to have a wide host range including both tropical and temperate species (Sutton, 1980; Crous *et al*., 1989a, b; Old and Yuan, 1994; Sharma, 1994; Yuan *et al*., 1995; Old *et al*., 2003).

Coniella australiensis Petr. was recorded as a leaf pathogen of *Eucalyptus* species in plantations and nurseries in the following tropical and temperate countries: Australia (Yuan *et al*., 1995), England, France, India, Israel, Netherlands, (Crous *et al*., 1989b), Japan (Kobayashi, 2007; Motohashi *et al*., 2010), Papua New Guinea (Shaw, 1984), Thailand, and Vietnam (Old and Yuan, 1994; Sharma, 1994). *Coniella australiensis* forms pycnidia irregularly over the necrotic areas (Park *et al*., 2000). Also, it can be found on dead branches of *Eucalyptus* following insect damage (Shaw, 1984).

Coniella fragariae (Oudem.) B.C.Sutton is the common species reported worldwide including Australia (Park *et al*., 2000; Carnegie, 2002), Brazil (Ferreira, 1989; Mendes *et al*., 1998), China (Park *et al*., 2000), Congo (Roux *et al*., 2000a), India (Sharma *et al*., 1985; Muthumary and Vanaja, 1986; Sharma, 1985), Indonesia, Sri Lanka, Vietnam (Old *et al*., 2003), United Kingdom, Canada, and several African countries (Sutton, 1980). *Coniella fragariae* prefers humid conditions for disease development (Griffiths *et al*., 2004). The spots start with grayish-black colour and later become yellow-brown in dry weather. The spots begin from the leaf margin with concentric rings of brown pycnidia evident even on small lesions and spread to form large blights. Heavily infested leaves can be completely covered by these blights and are shed prematurely (Sharma *et al*., 1985; Park *et al*., 2000; Griffiths *et al*., 2004).

Ferreira (1989) reported that *C. fragariae* was frequently found associating with *Cylindrocladium* species in Brazil.

Coniella castaneicola (Ellis and Everh.) B. Sutton was found in Australia (Langrell *et al*., 2008), Cuba, Florida, India (Nag Raj, 1993), Hawaii (Raabe *et al*., 1981), and South Africa (Roux and van Warmelo, 1990; Viljoen *et al*., 1992; Crous and van der Linde, 1993). It causes light brown roundish lesions (Park *et al*., 2000). Other four species are *C. eucalypticola* Nag Raj which was reported appearing on dead leaves of *Eucalyptus* in India (i.e. not pathogenic; Nag Raj, 1993); *C. granati* (Sacc.) Petr. and Syd. which was reported from *Eucalyptus* leaf litter in India (Soni and Jamaluddin, 1990) that can cause disease in nurseries (Sharma *et al*., 1985); *C. minima* B.C.Sutton and Thaung which occurred on leaf lesions of *E. camaldulensis* in Burma (Thaung, 2008b) and on *E. globulus* in Uruguay as an endophyte (Bettucci and Saravay, 1993); *C. petrakii* B.C.Sutton which was found in Burma (Sutton, 1980; Thaung, 2008), India, Nigeria, Tanzania, Sierra Leone, Switzerland (Sutton, 1980), and South Africa (Lundquist and Baxter, 1985).

***Cylindrocladium* Morgan (Teleomorph: *Calonectria* De Not.)**

Cylindrocladium species and their teleomorph are important damaging pathogens of *Eucalyptus* (Park *et al*., 2000; Crous, 2002; Old *et al*., 2003; Lombard *et al*., 2010c). They are basically soil-borne, root-infecting fungi but may also infect the above-ground parts of plants (Park *et al*., 2000). Twenty five species of *Cylindrocladium* were identified associated with *Eucalyptus* species in various countries such as Australia (Griffiths *et al*., 2004; Crous *et al*., 2006c; Lombard *et al*., 2010), Brazil (Blum and Dianese, 1993; Risede and Simoneau, 2001; Crous *et al*., 2006c; Lombard *et al*., 2010b), China (Zhou *et al*., 2008; Lombard *et al*., 2010b), Colombia (Rodas et al., 2005), Ethiopia (Gezahgne *et al*., 2003), India (Crous, 2002), Indonesia (Crous *et al*., 2006c; Lombard et al., 2010b), Japan (Kobayashi, 2007), Kenya (Roux *et al*., 2005), Laos (Old *et al*., 2003), Madagascar (Lombard *et al*., 2010b), Malaysia (Crous *et al*., 1989b), New Zealand (Gadgil, 2005), Russia (Schoch *et al*., 2000), South Africa (Crous *et al*., 2006c; Wright *et al*., 2007; Lombard *et al*., 2010b), Thailand (Crous *et al*., 2006c; Lombard *et al*., 2010b), Uganda (Roux *et al*., 2005), United States (Crous *et al*., 2006c), and Vietnam (Sharma, 1994; Crous *et al*., 2006c). They cause *Eucalyptus* diseases including leaf blight (Sharma and Mohanan, 1991; Booth et al., 2000; Rodas et al., 2005) and cutting rot (Sharma and Mohanan, 1982; Sharma et al., 1984; Schoch *et al*., 1999; Crous, 2002). Leaf blight is most devastating on *Eucalyptus* species (Booth *et al*., 2000; Crous and Kang, 2001; Carnegie, 2002; Crous, 2002; Rodas *et al*., 2005). Diseases were commonly found in the period of high humidity. They affect the growth of leaves and new shoots of young trees. They begin to appear as grayish water-soak tissue in young leaves and expand the leaf lesions with distortion, resulting premature leaf foliation. Small white fruiting bodies may appear on the margin of the lesions. Diseases in young *Eucalyptus* plants can be resulted from the carryover of pathogens from the infected nursery plants (Park *et al*., 2000; Old *et al*., 2003). Although *Cylindrocladium* species have been found on *Eucalyptus* worldwide they only cause severe damage in the tropics and sub-tropics. The causal agent of new outbreaks is usually indigenous to the region of the outbreak (Burgress and Wingfield 2002).

The characteristics of the hyphomycetes genus *Cylindrocladium* are having phialidic conidiogenous branches formed laterally from a stipe which grows on the penicillate conidiogenous-like structure (Booth and Gibson, 1973), stipes with no septa or a single septum near the point of emergence of the conidiogenous branches, and forming long sterile hyphae which have vesicles at the tips. Conidia are typically cylindrical in shape with one or more septa (Brown and Wylie, 1991; Crous and Wingfield, 1993; Crous, 2002). The common species associated with *Eucalyptus* leaf diseases is *C. quinqueseptatum* Boedijn and Reitsma (= *C. reteaudii*) (teleomorph: *Calonectria quinqueseptata* Figueiredo and Namekata), the most common and severe disease-causing agent in south-east Asia, India, and northern Australia (Bolland *et al.*, 1985; Old *et al*., 2003; Park *et al*., 2000; Crous, 2002), and in Brazil (Figueiredo and Namekata, 1967; Kang *et al*., 2001a). Crous (2002) commented *Cy. scoparium* Morgan (teleomorph: *Calonectria morganii* Crous, Alfenas and M.J.Wingf.) appears to be limited distribution to North and South America, it previously frequent confused with *Cy. pauciramosum* C.L. Schoch and Crous which occurs in many countries around the world. *Cy. scoparium* was reported as a foliar pathogen on *Eucalyptus* spp. in Brazil (Cruz and Figueiredo, 1960, 1961) and Costa Rica (Segura, 1970). Old *et al*. (2003) mentioned some other widely distributed species that are known to attack

Eucalyptus in South-East Asia. They are *Cy. insulare* C.L. Schoch and Crous (teleomorph: *C. insulare* C.L. Schoch and Crous), *Cy. parasiticum* Crous, M.J. Wingf. and Alfenas, *Cy. floridanum* Sobers and E.P. Seym. (teleomorph: *C. kyotensis* Terash.), *Cy. theae* (Petch) Subram. (teleomorph: *C. theae* Loos) and *Cy. pteridis* F.A. Wolf (teleomorph: *C. pteridis* Crous, M.J. Wingf. and Alfenas). In Brazil Cylindrocladium leaf disease has been reported causing by *Cy. ovatum* (Blum and Dianese, 1993; El-Gholl *et al*., 1993), *Cy. gracile* (Bugn.) Boesewinkel (teleomorph: *C.gracilis* Crous, Wingfield and Alfenas) (Blum and Dianese 1993), *Cy. reteaudii* (Bugn.) Boesewinkel (El-Gholl *et al*., 1997; Crous and Wingfield, 1992, 1994), *Cy. pteridis* Wolf, *Cy. floridanum, Cy. heptaseptatum* Sobers, Alfieri and Knauss, *Cy. theae* (Ferreira, 1989), *Cy. spathulatum* El-Gholl, Kimbrough, Barnard, Alfieri and Schoulties, *Cy. parasiticum* Crous, M.J.Wingf. and Alfenas (teleomorph: *C. ilicicola* Boedijn and Reitsma) (Crous *et al*., 1993a) and *Cy. variabile* Crous, Janse, Victor, Marais and Alfenas (teleomorph: *C. variabilis*) (Crous *et al*., 1993d).

Harknessia Cooke (Teleomorphs: _Wuestneia_ Auersw. ex Fuckel)

The genus *Harknessia* as circumscribed by recent revisions (Sutton, 1971a, 1980; Nag Raj and DiCosmo, 1981; Nag Raj, 1993), has in the past been heterogeneous. Several other genera are listed by Nag Raj as synonyms of *Harknessia*, namely *Caudosporella* Höhn. (based on *H. antarctica* Speg.), *Mastigonetron* Kleb. (based on *M. fuscum* Kleb., which has an apical conidial appendage and a *Wuestneia* teleomorph), and *Cymbothyrium* Petr. (based on *M. sudans* Petr.). Teleomorphs of *Harknessia* were proved to reside in *Wuestneia* Auersw. ex Fuckel in the *Diaporthales* (Reid and Booth, 1989).

Species of the coelomycete genus *Harknessia* are characterized by their stromatic to pycnidioid conidiomata, and darkly pigmented conidia with a distinct basal frill or stalk-like appendage formed from the persistence of the apical part of the conidiogenous cell, longitudinal striations, and rhexolytic sessesion (Sutton, 1971b; Nag Raj and Cosmo, 1981). The pycnidia erupt through the leaf surface and become somewhat acervular as black masses of conidia are exuded onto the lesion surface (Park *et al*., 2000). Leaf lesions are light brown, round to irregular in shape, somewhat surrounded by a chlorotic band (Crous *et al*., 1993f They may cause tip blight of young lateral shoots (Sutton, 1975). Teleomorphs of *Harknessia* is *Wuestneia* (*Melanconidaceae*, *Diaporthales*) (Kirk *et al*., 2008, Eriksson *et al*., 2003). Members of this genus occur as either plant pathogens or saprobes (Sankaran *et al.*, 1995a; Yuan *et al.*, 2000; Crous and Rogers, 2001; Farr and Rossman, 2001). Species of *Harknessia* occur on leaves and twigs of various gymnosperm and dicotyledonous hosts. *Eucalyptus* is particularly rich in *Harknessia* species (Lee *et al*., 2004).

Currently 17 species of *Harknessia* have been recorded on *Eucalyptus* from different parts of the world (Sankaran et al., 1995a; Yuan et al., 2000; Lee *et al*., 2004; Crous et al 2007f). A number of the known *Harknessia* species are associated with leaf spots and are thus assumed being pathogens, such as *H. eucalypti* Cooke, *H. fumaginea* B.C. Sutton and Alcorn apud B.C. Sutton, *H. gibbosa* Crous and C. Mohammed, *H. hawaiiensis* F. Stevens and E. Young, *H. insueta* B. Sutton and *H. uromycoides* (Speg.) Speg. (Crous *et al*., 1989b, 1993f). However, some species appear to be saprobes or unaggressive pathogens such as *H. ventricosa* B. Sutton and Hodges (Crous *et al*., 1989b). *Harknessia hawaiiensis* was also reported as a common endophyte of mature leaves of *E. globulus* in Uruguay (Bettucci and Saravay, 1993).

Harknessia eucalyptorum Crous, M.J.Wingf. and Nag Raj is commonly associated with *Eucalyptus* species in South Africa (Crous *et al*., 1993f). *Harknessia eucalypti* has been reported from the Australia, New Zealand, United States (Sutton, 1980) and Italy (Nag Raj and di Cosmo, 1981). *Harknessia uromycoides* is also one common species on *Eucalyptus* (Sutton and Pascoe 1989). It has been reported from Argentina, Australia, California, and Spain (Bonar, 1928). *Harknessia fumaginea* was reported in Australia and Brazil (Sutton, 1975). *Harknessia victoriae* Sutton and Pascoe was found only in Victoria (Sutton and Pascoe, 1989) and Tasmania (Yuan *et al*., 2000b).

***Mycosphaerella* Johanson and associated anomorphs**

Mycosphaerella Johanson is one of the largest genera of the ascomycetes, accommodating over 1800 species (Kirk *et al*., 2008). Species of *Mycosphaerella* and their anamorpths have adapted to proliferate as saprobes, plant pathogens, and even hyperparasites in different ecosystems (de Hoog *et al*., 1991; Goodwin *et al*., 2001; Jackson *et al*., 2004; Arzanlou *et al*., 2007). Approximately 80 pathogenic species have been associated with leaf diseases of *Eucalyptus* worldwide

(Crous, 1998, Maxwell *et al*., 2003, Crous *et al*., 2004c). Mycosphaerella Leaf Disease is one of the most important diseases which damage *Eucalyptus* plantations and is likely to become increasingly serious in the future. (Lundquist and Purnell, 1987; Carnegie *et al*., 1994; Crous and Wingfield, 1996; Dungey *et al*., 1997; Crous *et al*., 2006g).

Crous (1998) reported *Mycosphaerella* species and a number of their anamorphs associated with *Eucalyptus*. They include *Colletogloeopsis*, *Colletogloeum*, *Coniothyrium*, *Phaeophleospora*, *Pseudocercospora*, *Sonderhenia*, *Stagonospora*, *Stenella*, and *Uwebraunia*. Recently several additional species have been described elsewhere (Braun and Dick, 2002; Carnegie and Keane, 1998; Crous *et al*., 2004c, 2006g; Hunter *et al*., 2004; Maxwell *et al*., 2003). They damage prevalently the juvenile leaves and shoots of *Eucalyptus* trees which result in premature defoliation, twig cankers and stunting of tree growth, shoot die-back, and even tree death (Lundquist and Purnell, 1987, Crous, 1998, Park *et al*., 2000).

The damage has mostly been attributed to *Mycosphaerella cryptica* (Cooke) Hansf. and *M. nubilosa* (Cooke) Hansf. They cause severe defoliation and leaf blotch symptoms on *Eucalyptus* species in Australia, New Zealand, South Africa, and South-East Asia (Cheah, 1977; Carnegie *et al*., 1994; Crous and Wingfield, 1996; Wingfield *et al*., 1996a, b; Dungey *et al*., 1997). In general, *Mycosphaerella* species and their anomorphs devastate and cause shoot blight of *Eucalyptus*. Example are *M. grandis* Carnegie and Keane in South-Eastern Australia (Carnegie and Keane, 1994); *M. heimii* Crous (anamorph: *Pseudocercospora heimii* Crous) in Madagascar (Crous and Swart, 1994); *M. marksii* in Indonesia, South Africa, Portugal and South America (Crous, 1998); *M. suberosa* in Brazil and Western Australia (Carnegie *et al*., 1997); *M. suttoniae* (anamorph: *Phaeophleospora epicoccoides*) in Indonesia and Brazil (Crous, 1998); *M. walkeri* in South America and Portugal (Crous, 1998); and *Phaeophloespora destructans* (M.J. Wingf. and Crous) Crous, F.A. Ferreira and B. Sutton in South-East Asia (Wingfield *et al*., 1996b).

The identification of *Mycosphaerella* species is extremely difficult because of the overlapping morphological characteristics and the co-occurrence of many different taxa in the same leaf lesion (Crous *et al*., 2004a, c, 2007h, 2008; Crous and Groenewald, 2005; Burgess *et al*. 2007; Cheewangkoon et al. 2008). Ascospore germination patterns, characteristics of the fungi in culture, and anamorph morphology have been used to distinguish some of these taxa (Crous, 1998; Crous *et al*., 2004d). Incorporating DNA sequence data allowed more accurate species delimitation (Crous *et al*., 2000a, 2001a, b). Crous *et al*. (2006g) suggested that there should be over 60 *Mycosphaerella* speceis on *Eucalyptus*. Based on the number of *Mycosphaerella* species on other plant species (Crous and Mourichon, 2002; Crous and Braun, 2003; Taylor *et al*., 2003) and the number of *Eucalyptus* (which is more than 800 species; Brooker, 2002), it can be expected that many more *Mycosphaerella* species and their anamorphs on *Eucalyptus* can be found in the future when there are more collections and studies. Moreover, when additional gene sequences are applied, other cryptic species can be identified (Crous *et al*., 2004d).

***Quambalaria* J.A. Simpson**

Quambalaria leaf and shoot blight of *Eucalyptus* characterised by the occurrence of powdery white fungal spore masses on the lesions (Wingfield *et al*.; 1993; Simpson; 2000). Spore pustules rupturing through the waxy leaf cuticle. They composed a dense layer of conidiophores borne on a plectenchymatous stroma, hyaline conidia forming short simple or branched chains, sympodial proliferation (Simpson, 2000; Paap *et al*., 2008; Pegg *et al*., 2008). The disease infects the young growing shoots and tips, causing spotting, necrosis and distortion of young, expanding leaves, shoots and green stems (Alfenas *et al*., 2004; Andrade *et al*. 2005). Large irregular masses can occur along the edges of leaves or on the midribs, resulting in distortion and twisting of the leaf. Heavily infected trees are often stunted and multi-branched and are characterized by shoot dieback. Trees can grow through the damage, but some remain suppressed (Griffiths *et al*., 2004). High temperatures and leaf wounds from pruning and removing of sprouts offer favorable conditions for pathogen development (Ferreira *et al*., 2007).

The first record of a species of *Quambalaria* causing damage to eucalypts was on nursery seedlings of *Eucalyptus maculate* in New South Wales, Australia, in the 1950s (Walker and Bertus, 1971). The pathogen was described as *Ramularia pitereka*, but following re-examination of the four known species of *Ramularia* on eucalypts, it was transferred to the new genus *Quambalaria* (Simpson, 2000). A new family, Quambalariaceae, has since been described (de Beer *et al*., 2006) for species of *Quambalaria* that include a number of eucalypt (species of the genus *Eucalyptus* and *Corymbia*) pathogens. However, the taxonomic status of this fungus has been questioned (de Beer *et al*., 2006) and, as no type culture exists, it cannot be confirmed.

Five species of *Quambalaria* have been identified from *Eucalyptus*, namely *Q. cyanescens* (de Hoog and G.A. de Vries) Z.W. de Beer, Begerow and R. Bauer, *Q. eucalypti* (M.J. Wingf., Crous and W.J. Swart) J.A. Simpson, *Q. pitereka* (J. Walker and Bertus) J.A. Simpson, *Q. pusilla* (U. Braun and Crous) J.A. Simpson and *Q. simpsonii* Cheew. and Crous (Walker and Bertus 1971, Bertus and Walker 1974, Wingfield et al. 1993, Simpson 2000, Carnegie 2007, Paap et al. 2008, Pegg *et al*., 2008; Cheewangkoon et al., 2009). *Q.* coryecup T. Paap is only the causal agent of extensive perennial canker disease on *Corymbia calophylla* in Western Australia (Paap *et al*., 2008).

Quambalaria eucalypti (as *Sporothrix eucalypti*) is the first species occurring on *Eucalyptus* in South Africa, but was not consider as serious pathogen (Wingfield *et al.* 1993). Roux *et al*. (2006) also reported its pathology in which being associated with leaf spots and serious shoot infections on *Eucalyptus dunnii* and *E. smithii* in South Africa. Later it has been reported as a destructive pathogen causing stem girdling on seedlings and leaf and shoot blight on mini-stumps *Eucalyptus* spp. in Brazil (Alfenas et al. 2001, Zauza *et al*. 2003). It has also been identified from twig lesions on *E. globulus* in Uruguay (Bettucci et al. 1999). Recently, Pegg *et al*. (2008) found that *Q. eucalypti* occurring on *Eucalyptus* spp. in commercial plantations in both subtropical and tropical regions of eastern Australia.

Quambalaria cyanescens (as *Sporothrix cyanescens*) was originally described from human skin (de Hoog and de Vries, 1973) and the first record on eucalypts was isolated from *E. pauciflora* in New South Wales, Australia (de Beer *et al*., 2006; Paap *et al*., 2008; Pegg *et al*., 2008). More recently, *Q. cyanescens* was identified from bark beetles collected from a range of host tree species, including *Tilia*, *Quercus* and *Ficus*, in Hungary, Bulgaria and the Mediterranean (Kolarik *et al*., 2006). Other three species are seldom found on Eucalyptus are *Quambalaria pitereka* was found on *Eucalyptus* only in China (Zhou *et al*., 2007), *Q. pusilla* and *Q. simpsonii* has been attributed to specific to *Eucalyptus* species (Simsom 2000; Cheewangkoon *et al*., 2009).

2.7.5 Phylogenetic studies of selected fungi on *Eucalyptus*

From the last decade, molecular biology has developed rapidly with a variety of techniques which are now available to mycologists to help understanding the phylogenetic relationships of species and genera and concepts at higher taxonomic levels. Modern molecular methods are now being used to detect cryptic species, separate closely related species, and determine phylogenies. Molecular techniques are used them to compare genetic materials and draw conclusions about the relatedness of taxa. It also can prove anamorph and teleomorph connection.

Schizoparme* and *Coniella

The anamorph *Coniella* and *Pilidiella* have similar morphological characteristics which can be separated by using conidial pigmentation character. *Pilidiella* has hyaline to pale brown conidia which in *Coniella* are dark brown (von Arx, 1981). Later Sutton (1980) and Nag Raj (1993) treated two genera as synonymous, the older name *Coniella* having priority. Samuels, Samuels *et al*. (1993) linked several *Coniella* anamorphs to species of Schizoparme (Diaporthales). Castlebury *et al*. (2002) studied using DNA-based analyses of Diaporthales, showed that *Schizoparme* and their anomorphs fall within *Schizoparme*-complex clade. The clade represented of an undescribed family which may eventually be recognized as its own family. It also suggested the anamorph genera *Pilidiella* should be distinct from *Coniella* and retained as separated genera. Recently, Rossman et al. (2007) confirmed the placement of *Schizoparme*-complex and introduced new family Schizoparmeaceae to accommodate those taxa and also commented in distinguish of anamorphic state *Pilidella* and *Coniella*, by the three layered ascomatal wall and the basal pad from which the conidiogenous cells originate.

van Niekerk *et al*. (2004) clarified the taxonomic status of the type species of *Pilidiell*a and *Coniella* using sequences of the internal transcribed spacer region (ITS1, ITS2), 5.8S gene, large subunit (LSU) and elongation factor 1-a gene (EF 1-a). The result supported the separation of *Coniella* from *Pilidiella*, *Pilidiella* is characterised by having species with hyaline to pale brown conidia (avg. length: width >1.5), in contrast to the dark brown conidia of *Coniella* (avg. length: width ≦1.5). This study also presented the new species *P. eucalyptorum* which was previously treated as *C. fragariae*, this isolate associated with leaf spots of *Eucalyptus* spp. *Pilidiella destruens* was described and linked as anamorph of *Schizoparme destruens*, which is associated with twig dieback of *Eucalyptus* spp. in Hawaii.

Calonectria* and *Cylindrocladium

Early studies on the taxonomy of *Calonectria* spp. and *Cylindrocladium* spp. had focused on using morphological characteristics in combination with biological characters (Boedijn and Reitsma 1950, Peerally 1991, Crous *et al.* 1992, Crous and Wingfield 1994,Crous 2002). More recently, Phylogenetic studies on *Calonectria* and its *Cylindrocladium* anamorphs have substantially influenced the taxonomy of these genera. Application of molecular techniques and particularly DNA sequence comparisons have revolutionized the taxonomy of *Calonectria* and *Cylindrocladium*, several studies have elucidated cryptic species in the genus (Schoch *et al.*, 1999; Kang *et al.* 2001a, 2001b, Henricot and Culham 2002, Crous *et al.* 2006c, Lombard *et al.* 2009, 2010a).

Several molecular approaches have been employed that include total protein electrophoresis (Crous *et al.* 1993a, El-Gholl *et al.* 1993), isozyme electrophoresis (El-Gholl *et al*., 1992, 1997, Crous *et al.,* 1998a), random amplification of polymorphic DNA (RAPD) (Overmeyer *et al*., 1996, Victor *et al*., 1997, Schoch *et al*., 2000, Risède and Simoneau 2004) restriction fragment length polymorphisms (RFLP) (Crous *et al.* 1993b, 1995b, 1997c, Jeng *et al.* 1997, Victor *et al.* 1997; Risède and Simoneau 2001) and DNA hybridisation (Crous *et al*., 1993b, 1995b, 1997c, Victor *et al.* 1997). Although the above-mentioned techniques have been useful, DNA sequence comparisons and associated phylogenetic inference have had the most dramatic impact on the taxonomy of *Calonectria* and are most widely applied today.

The first phylogenetic study of *Calonectria* and *Cylindrocladium* was done by Jeng *et al.* (1997), it was able to distinguish between *Cy. scoparium* and *Cy. floridanum* isolates using 5.8S ribosomal RNA gene and flanking internally transcribed spacers (ITS) sequences. Subsequently, it was found that this gene region contains few informative characters (Crous *et al.* 1999b, Schoch *et al.* 1999, Risède and Simoneau 2001, Schoch *et al.* 2001). Therefore, the β-tubulin (Schoch *et al.* 2001) and histone H3 (Kang *et al.* 2001a) gene regions have been applied in order to allow for improved resolution in separating species. The first complete DNA sequence-based phylogenetic study using partial β-tubulin gene sequences (Schoch *et al.*, 2001) translation elongation 1-alpha (TEF-1α) and calmodulin (Crous *et al.* 2006c, Lombard *et al*., 2010c).

Wuestneia* and *Harknessia

The placement of *Wuestneia* in the *Melanconidaceae* has been unequivocally recognized by Barr (1990) and Eriksson *et al*. (2001). In a preliminary overview of the *Diaporthales* by Castlebury *et al.* (2002), six major lineages in the order were identified based on the LSU nrDNA sequences, of which the *Melanconidaceae* were defined in a restricted sense including the type genus *Melanconis* only, showing close affinity with the *Gnomoniaceae* and excluding *Wuestneia*/*Harknessia*.

Lee *et al*. (2004) used a neighbour joining analysis of the LSU nrDNA sequences of *Harknessia* species to show the placement of *Wuestneia*/*Harknessia* as a sister clade of the Cryphonectriaceae and Schizoparmeaceae, which is far apart from the Melanconidaceae. In terms of anamorphic features, the *Wuestneia*/*Harknessia* clade is closer to the members of Melanconidaceae, which have holoblastically produced brown, unicellular conidia in stromatic conidiomata (Sutton 1980). Currently there is no family that accommodates the *Schizoparme/Pilidiella* complex. The similar-looking anamorph genus *Apoharknessia* lacks a known teleomorph and is phylogenetically distinct from *Harknessia* but also is not allied with any known family in the Diaporthales (Lee *et al*,. 2004; Rossman *et al*., 2007).

***Mycosphaerella* and associated anomorphs**

Early phylogenetic analyses base on ITS sequence data concluded that *Mycosphaerella* revealed most the anamorph genera were clustered in well-defined clades within *Mycosphaerella*. (Stewart *et al*., 1999: Crous *et al*., 1999a; Goodwin *et al*., 2001; Crous *et al*. 2000a, 2001a, b). However, once multi-gene data were applied in later studies such as ITS, ACT, HIS, mtSSU, EF-1α and RPB2, showed that *Mycosphaerella* is polyphyletic (Hunter *et al*., 2006b; Crous *et al*., 2007a, b; Schoch *et al*., 2006; Arzanlou *et al*., 2007; Batzer *et al*., 2008).

In recent years, many phylogenetic studies have separated *Mycosphaerella* complex into *Davidiella* species with *Cladosporium* anamorphs (*Davidiellaceae*) (Braun *et al*., 2003; Crous *et al*., 2007b; Schubert *et al*., 2007a,b; Dugan *et al*., 2008), *Schizothyrium* species with *Zygophiala* anamorphs (*Schizothyriaceae*) (Batzer *et al*., 2008), *Teratosphaeria* species with many anamorphs (*Teratosphaeriaceae*) (Crous *et al*., 2007a, h), and *Mycosphaerella* species, also with numerous anamorph genera (*Mycosphaerellaceae*) (Crous and Braun, 2003; Arzanlou *et al*., 2007), all belonging to the *Capnodiales* in the *Dothideomycetes* (Crous *et al*., 2009c; Schoch *et al*., 2006, 2009).

Quambalaria

The genus *Quambalaria* was transferred from eucalypts pathogens which previously classified in genera such as *Sporothrix* and *Ramulariaare,* it has been suggested that belong to the basidiomycete orders *Exobasidiales* or *Ustilaginales* (Simpson 2000). The phylogenetic relationship of *Quambalaria* spp. has been addressed by Beer *et al*. (2006), using ITS and LSU sequence data cooperate with transmission electron-microscopic studies of the septal pores to consider the ordinal relationships of *Q. eucalypti* and *Q. pitereka*.

The LSU sequence analysis concluded that *Quambalaria* spp. form a monophyletic clade in the *Microstromatales,* an order of the *Ustilaginomycetes*. Sequences from the ITS region confirmed that *Q. pitereka* and *Q. eucalypti* are distinct species. In this study, the ex-type isolate of *Fugomyces cyanescens*, together with another isolate from *Eucalyptus* in Australia, constitute a third species was *Q. cyanescens*. Moreover, based on their unique ultrastructural features and the monophyly of the three *Quambalaria* spp. A new family, *Quambalariaceae* was proposed to accommodate those *Quambalaria* species. Zhou *et al*. (2007) also used ITS sequence data to identify the causal agent of the disease in China including

Quambalaria cyanescens, *Q. eucalypti* and *Q. pitereka*, in addition, *Q. simpsonii* from Australia and Thailand (Cheewangkoon *et al*., 2009).

2.8 Number of fungi on *Eucalyptus*

Many members of the *Eucalyptus* contain a range of substrates and oils that support a highly diverse fungal community, making them favourable hosts to numerous plant pathogenic and saprobic fungi. According to the estimated 10:1 ratio between the numbers of fungal species and hosts (Harksworth 1991), the approximately 800 current species of *Eucalyptus* (Brooker, 2002) are likely to have about 8000 species of associated fungi. There have been numerous publications listing and describing the plant-pathogenic fungi occurring on eucalypts in various countries where these trees are grown as ornamentals or in plantations for timber and paper fibre (Old and Davison 2000, Park *et al*., 2000). Sankaran *et al*. (1995b) alone listed fungal species occurring on *Eucalyptus* and reported 1350 species. In the period 1995–2008, a further 165 novel species from *Eucalyptus* have been described, and many more were added recently (Cheewangkoon *et al*., 2008, 2009; Lombard *et al*., 2010c; Andjic *et al*., 2010; Aveskamp *et al*., 2010; Crous *et al*., 2009b, f; Taylor *et al*., 2009; van Wyk *et al*., 2009).

2.8.1 Checklist of fungi on *Eucalyptus* (1880-1994)

Sankaran *et* al. (1995b) listed fungal species occurring on *Eucalyptus* and reported 1,350 species in more than 630 genera and 120 families. They are geographically distributed in more than 90 countries in Africa (Cameroon, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mauritania, Mauritius, Morocco, Nigeria, Seychelles, Sierra Leone, Sudan, Tanzania, Togo, Tunisia, Uganda, Algeria, Zambia, Zimbabwe, South Africa), America (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Paraguay, Peru, Surinam, Uruguay, Mexico, Venezuela, United States), Asia (Bhutan, Brunei, Burma, China, India, Indonesia, Iran, Iraq, Israel, Japan, Kuwait, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam), Caribbean (American Virgin Islands, Cuba, Dominican Republic, Jamaica, Puerto Rico, Trinidad, Tobago), Europe (British Isles, Denmark, former USSR, France, Georgia, Germany, Greece, Italy, Malta, Netherlands, Poland, Portugal, Rumania, Russia, Spain, UK, Ukraine), Mediterranean (Cyprus, Palestine), Oceania (Australia, New Zealand, Solomon Islands), Pacific Ocean (American Samoa, Fiji, Samoa, Vanuatu).

2.8.2 Updated checklist of fungi on *Eucalyptus* (1995-present)

This checklist is reproduced from Farr *et al*. (2005b) with some modifications and more updated informations.

Table 2.3 Updated checklist of fungi on *Eucalyptus* (1995-present)

FUNGI	LOCATIONS AND PUBLICATIONS
Alternaria alternata	Brazil (23; 25:156) India (260)Japan (135) Uruguay (24; 25)
Alternaria longipes	India (260)
Alternaria sp.	Brazil (156)
Alternaria tenuissima	Brazil (156)
Alysidiella parasitica	South Africa (231)
Antennariella placitae	Australia (44)
Anthostomella eucalypti	Australia (146)
Anungitopsis amoena	Cuba (94;117) Madagascar (59)South Africa (59)
Aplosporella yalgorensis	Australia (233)
Arthrinium phaeospermum	Uruguay(24) India (260)
Arthrinium sp.	Uruguay (23;25)
Arthrobotrys oligospora	India (260)
Arthrobotrys sp.	Brazil (156)
Ascocoma eucalypti	Australia (21)
Aspergillus aculeatus	India (260)
Aspergillus candidus	India (260)
Aspergillus flavus	India (260)
Aspergillus niger	India (260)
Aspergillus sp.	Brazil (156)
Asteromella sp.	Australia (214)
Aulographina eucalypti	Australia (214) Brazil (156) Chile (254) Madagascar (59)South Africa (203)
Aureobasidium pullulans	Uruguay (25;23)

FUNGI	LOCATIONS AND PUBLICATIONS
Bagadiella lunata	Australia (44)
Bagadiella sp.	Australia (44)
Blastacervulus eucalypti	Australia (44)
Beltrania malaiensis	India (260)
Beltrania rhombica	India (260)
Beltraniella portoricensis	India (260)
Beltraniopsis esenbeckiae	Venezuela (39)
Bertia antennaroidea	Tasmania (266)
Bipolaris sp.	Brazil (156)
Biscogniauxia capnodes	Brazil (129) Hawaii (129)
Biscogniauxia mediterranea	Brazil (129)
Biscogniauxia uniapiculata	Hawaii (129)
Bispora sp.	Brazil (156)
Blastacervulus eucalypti	Australia (44)
Botryodiplodia sp.	Brazil (156)
Botryosphaeria australis	Australia (16;66)
Botryosphaeria dothidea	Australia (16;223) Brazil (156) China (262) New Zealand (98) South Africa (226;227) Uruguay (24;68) Venezuela (159)
Botryosphaeria eucalypticola	Australia (183)
Botryosphaeria eucalyptorum	South Africa (16; 97;182;183;220;221;222; ;223;229; 277) South Africa, Mpumalanga (16;223)
Botryosphaeria lutea	Australia (91)
Botryosphaeria mamane	Venezuela (159)
Botryosphaeria parva	Australia (16) Ethiopia (202) Hawaii (97;220)Indonesia (220) South Africa (97;220)
Botryosphaeria rhodina	Australia (30) Brazil (156) Mexico (30) Venezuela (30)
Botryosphaeria ribis	Australia (225;16) Netherlands (16)
Botryosphaeria sp.	Australia (178;267) Brazil (156) China (276) Ethiopia (99) Japan (135)Kenya (203) Mozambique (203) Tanzania (203) Zambia (203)
Botrytis cinerea	Brazil (156) New Zealand (98;154) Poland (162) Uruguay (24) Ukraine (93)

FUNGI	LOCATIONS AND PUBLICATIONS
Brachysporiella gayana	Samoa (155)
Brobdingnagia eucalypticola	Australia (218)
Calonectria avesiculata	Florida (83)
Calonectria brasiliensis	Brazil (142)
Calonectria cerciana	China (144) Florida (83) Hawaii (83;240) India (83) Indonesia (83) Louisiana (83) Mauritius (83) North Carolina (83) Oregon (83) South Carolina (68;83) Thailand (83) United States (68) Virginia (83)
Calonectria eucalypti	Indonesia (143)
Calonectria gracilipes	Colombia(68;141)
Calonectria gracilis	Brazil (83)
Calonectria ilicicola	Brazil (83) India (83) Kenya (83) Malaysia (83) United states (83)
Calonectria indusiata	Australia (83) Brazil (83) Florida (83) Germany (83) Hawaii (83) Indonesia (83) Mauritius (83) North Carolina (83)
Calonectria insularis	Brazil (83)
Calonectria kyotensis	Brazil (83) Florida (83) Georgia (83) Hawaii (83) India (83) Louisiana (83) Minnesota (83) North Carolina (83) Ohio (83)
Calonectria leguminum	Brazil (83)
Calonectria macroconidialis	South Africa (68;83)
Calonectria morganii	Brazil (83) United States (64)
Calonectria multiseptata	Indonesia (62;68;83)
Calonectria ovata	Brazil (83)
Calonectria pauciramosa	Brazil (83;144) China (142;144) Kenya (83;142) South Africa (142) Uruguay (142) Italy (83)
Calonectria pseudoreteaudii	China (144)
Calonectria pseudoscoparia	Ecuador (143)
Calonectria pteridis	Brazil (83;68) South Africa (61) India (83) United States (83)
Calonectria pyrochroa	Brazil (83) India (83) Kenya (83) Malaysia (83)
Calonectria queenslandica	Australia (144)

FUNGI	LOCATIONS AND PUBLICATIONS
Calonectria reteaudii	Viet Nam (68) Australia (68;83) India (83) Indonesia (83;144) Laos (83) Madagascar (68;83;144) Malaysia (83) Mauritius (83) Papau New Guinea (83) Sri Lanka (83) Thailand (68;83;144) Viet Nam (68;83)
Calonectria scoparia	Argentina (142)Brazil (83;142)
Calonectria spathiphylli	Brazil (83)
Calonectria spathulata	Brazil (83;142;144)
Calonectria sulawesiensis	Indonesia (143)
Calonectria terrae-reginae	Australia (144)
Calonectria variabilis	Brazil (83)
Calonectria zuluensis	South Africa (142)
Catenophoropsis eucalypticola	New Zealand (279)
Cephaleuros virescens	China (45)
Cephalosporium acremonium - (Acremonium strictum)	India (260)
Cephalosporium sp.	Brazil (156)
Ceratocystis atrox	Australia (24;63; 114; 242; 243; 247; 248)
Ceratocystis eucalypti	Australia (18; 178; 247;257;258)
Ceratocystis fimbriata	Brazil (201) Congo, Republic of the (196;197;201) South Africa (201) Uganda (199;201) Uruguay (18;19;201)
Ceratocystis fimbriatomima	Venezuela (242;247;248)
Ceratocystis moniliformis	Australia (178) Ecuador (114) South Africa (114;131;201;232) South Africa, Mpumalanga (8) Tanzania (114)
Ceratocystis moniliformopsis	Australia (8;114;131;232) South Africa (232) Tanzania (8)
Ceratocystis neglecta	Colombia (192;247;248)
Ceratocystis pirilliformis	Australia (18;114; 131;170; 201;242; 243; 246;247;248)South Africa (170;201)
Ceratocystis sp.	Kenya (203) Malawi (203) Tanzania (203) Brazil (156;276)
Ceratocystis zombamontana	Malawi (115;247)
Cercosperma arnaudii	Venezuela (39)
Cercosperma longispora	India (260)

FUNGI	LOCATIONS AND PUBLICATIONS
Cercospora epicoccoides - (*Phaeophleospora epicoccoides*)	Taiwan (45)
Cercospora eucalypti - (*Phaeophleospora eucalypti*)	Brazil (156) China (45) Pakisatan (4)
Cercospora eucalyptorum	Paraguay (54;82)
Cercospora sp.	China (45)Korea (47)
Cerebella andropogonis	Uruguay (23)
Ceuthospora innumera	Australia (267) Chile (254) India (174)
Chaetomella raphigera	India (260)
Chaetomium sp.	Brazil (156)
Chalara eucalypti - (*Thielaviopsis eucalypti*)	Australia (133) Tasmania (133)
Chlamydomyces palmarum	India (260)
Chrysoporthe austroafricana	Malawi (167) Mozambique (167) South Africa (108; 107;110;111;167) Zambia (167)
Chrysoporthe cubensis	Australia (107;108;110; 111;167)Brazil (111) Cameroon (111)China (276) Colombia (107;110; 111;167) Congo, Democratic Republic of the (107;110;167)Cuba (110;111) Florida (111) Hawaii (107;109;110; 111; 167) Indonesia (107;108;110; 167) Mexico (107;110; 167) Mozambique (1667) Puerto Rico (111) South America (111) Suriname (111;250) Venezuela (167;107)
Chrysoporthe doradensis	Ecuador (111;107)
Chrysoporthe sp.	India (111) Kenya (203) Malawi (203) Mozambique (203) Zambia (203)
Cibiessia dimorphospora	Australia (75;77)
Cibiessia nontingens	Australia (75)
Ciliosporella tuberculiformis	Tasmania (265)
Civisubramaniania eucalypti	India (260)
Cladoriella eucalypti	Africa (69)
Cladoriella paleospora	Australia (44)
Cladoriella rubrigena	Australia (44)
Cladosporium cladosporioides	China (273) India (260)Uruguay (24)
Cladosporium eucalypti	China (273) Italy (94)
Cladosporium oxysporum	India (260)Uruguay (23;25)
Cladosporium sp.	Brazil (156)

FUNGI	LOCATIONS AND PUBLICATIONS
Cladosporium spongiosum	India (260)
Clypeophysalospora latitans	Australia (132)
Coleophoma empetri	India (260)
Colletogloeopsis blakelyi	Australia (231)
Colletogloeopsis considenianae	Australia (231)
Colletogloeopsis dimorpha	Australia (231)
Colletogloeopsis gauchensis	Uruguay (51)
Colletogloeopsis sp.	Australia (77)
Colletogloeopsis stellenboschiana	South Africa (70) Western Cape (70)
Colletogloeopsis zuluense	China (50)
Colletogloeopsis zuluensis	KwaZuluNatal (51)South Africa (51)
Colletotrichum boninense	South Africa (148;213)
Colletotrichum eucalypti	Brazil (156)
Colletotrichum gloeosporioides	Australia (178) Brazil (156) Myanmar (236) South Africa (228)
Colletotrichum sp.	Brazil (156) China (45)
Coniella australiensis	Japan (135)
Coniella castaneicola	Australia (178) Brazil (156) India (260)
Coniella fragariae	Brazil (156) Congo, Republic of the (197)
Coniella minima	Myanmar (236)
Coniella petrakii	Myanmar (236)
Coniochaeta pulveracea	Tasmania (266)
Coniophora hanoiensis	Hawaii (103;104)
Coniophora marmorata	Hawaii (103;104)
Coniothyrium eucalypti - (Phoma eucalyptica)	Pakistan (4)
Coniothyrium eucalypticola	Australia (82)
Coniothyrium kallangurense	Australia (82)China (45)
Coniothyrium ovatum	Australia (82) New Zealand (280)
Coniothyrium sp.	Ethiopia (99) South Africa (82)
Coniothyrium zuluense	Ethiopia (101) Hawaii (49) Malawi (203) Mexico (200) Mozambique (203)South Africa (255)
Cordyceps sp.	Venezuela (241)
Corticium sp.	China (45)
Corynespora cassiicola	India (260)
Corynespora sp.	India (252)

FUNGI	LOCATIONS AND PUBLICATIONS
Cryphonectria cubensis	Australia (163) Brazil (156;166;178; 211) Cameroon (40;165;197;211;230) China (163) Colombia (165;166) Congo, Republic of the (165;197) Hawaii (165;211) Hong Kong (211) Malaysia (165) India (211) Indonesia (163;164;165;166) North America (134)South Africa (163;240;164;165;166) Thailand (163) Venezuela (163;164;165;241)
Cryphonectria eucalypti	Australia (250) South Africa (250)
Cryphonectria gyrosa	India (111)
Cryphonectria havanensis - (Endothia havanensis)	Brazil (156) Congo, Democratic Republic of the (40;108) Japan (109;135)
Cryphonectria nitschkei	Japan (111)
Cryphonectria parasitica	Japan (111)
Cryphonectria radicalis	South Africa (166)
Cryphonectria sp.	Brazil (156)
Cryptodiaporthe curvata	Tasmania (266)
Cryptophiale udagawae	Brazil (89)
Cryptophialoidea manifesta	Brazil (107)
Cryptosporiopsis edgertonii	New Zealand (281)
Cryptosporiopsis eucalypti	Australia (178;208) Hawaii (208) India (208) New Zealand (279) Uganda (199)
Cryptostictis eucalypti	China (45)
Cuphophyllus grossulus	Spain (138)
Curvularia eragrostidis	India (260)
Curvularia lunata	India (260)Uruguay (25)
Curvularia pallescens	India (260)
Curvularia sp.	Brazil (156)
Curvularia tuberculata	India (260)
Cylindrocarpon destructans - (Cylindrocarpon destructans var. destructans)	India (260)
Cylindrocarpon sp.	Brazil (156)
Cylindrocladiella camelliae	Brazil (83;251)
Cylindrocladiella elegans	South Africa (251)
Cylindrocladiella infestans	Brazil (251)
Cylindrocladiella lageniformis	Brazil (251;83)

FUNGI	LOCATIONS AND PUBLICATIONS
Cylindrocladiella parva	India (83) South Africa (83)
Cylindrocladiella peruviana	Brazil (156;251)South Africa (83;251)
Cylindrocladiella sp.	Brazil (156)
Cylindrocladium candelabrum	Brazil (190;209)
Cylindrocladium clavatum - (*Cylindrocladium gracile*)	Brazil (156)
Cylindrocladium crotalariae - (*Cylindrocladium parasiticum*)	Brazil (156)
Cylindrocladium curvatum	India (83)
Cylindrocladium floridanum	India (260)
Cylindrocladium gracile	Brazil (83) India (83) KwaZuluNatal (190) South Africa (83;190) Viet Nam (83)
Cylindrocladium graciloideum	Colombia (141)
Cylindrocladium hurae	Thailand (83)
Cylindrocladium ilicicola	Brazil (156)
Cylindrocladium insulare	Viet Nam (64)
Cylindrocladium multiseptatum	Indonesia (144;209)
Cylindrocladium ovatum	Brazil (62; 156; 190; 209)
Cylindrocladium parasiticum	Brazil (156)
Cylindrocladium parvum - (*Cylindrocladiella parva*)	India (260)
Cylindrocladium pauciramosum	Russia(209) South Africa (259) Viet Nam (64)
Cylindrocladium penicilloides	Brazil (156)
Cylindrocladium pteridis	Brazil (156;190)
Cylindrocladium quinqueseptatum - (*Cylindrocladium reteaudii*)	Australia (178)Brazil (156) Madagascar (59)
Cylindrocladium reteaudii	Madagascar (67) Thailand (67)
Cylindrocladium scoparium	Argentina (135)Brazil (156) Japan (135) New Zealand (98)
Cylindrocladium scoparium var. *brasiliensis* - (*Cylindrocladium scoparium*)	Brazil (156)
Cylindrocladium sp.	Brazil (156) China (45;99;276) Kenya (203)
Cylindrocladium spathulatum	Colombia (190;191)
Cylindrocladium theae	Congo, Republic of the (197)
Cyphellophora eucalypti	Australia (44)
Cystostereum murraii - (*Cystostereum murrayi*)	Hawaii (104)
Cytospora abyssinica	Ethiopia (2)

FUNGI	LOCATIONS AND PUBLICATIONS
Cytospora agarwalii	India (2)
Cytospora australiae var. australiae	Argentina (2)
Cytospora australiae var. foliorum	Georgia, Republic of (2)
Cytospora austromontana	Australia (2)
Cytospora berkeleyi	California (2)
Cytospora chrysosperma	California (2)
	South Africa (2)Uruguay (23;24;25)
Cytospora diatrypelloidea	Australia (2;231)
Cytospora disciformis	Australia (2) Uruguay(2)
Cytospora eucalypticola	Australia (25;178;267) New Zealand (282)
	Myanmar (236)Uruguay (2;23;25)
Cytospora eucalyptina	Argentina (2) Colombia (2) Mexico (2)
Cytospora nitschkii - (*Cytospora nitschkei*)	Ethiopia (2)
Cytospora sp.	Brazil (156) Congo, Republic of the (197)
	Ethiopia (99) Indonesia (2) South Africa (2)
	South Africa, Cape Province (2) Thailand (2)
	Uganda (199)
Cytospora valsoidea	Indonesia (2)
Cytospora variostromatica	Australia (2)
Dactylaria affinis	India (260)
Dactylaria eucalypti	India (260)
Dactylaria purpurella	India (260)
Dendryphion sp.	Brazil (156)
Diaporthe eucalypticola	Australia (178;268)
Diaporthe fusispora	Tasmania (266)
Diatrype flavovirens	Spain (1)
Diatrype oregonensis	California (239)
Dichomera eucalypti	Australia (233)
Dichomera eucalyptii	Australia (20) Uruguay (179)
Dichomera versiformis	Uruguay (179)
Dinemasporium strigosum	Australia (267)
Diplodia eucalypti	Australia (16)
Diplodia versiformis	Australia (16)
Dissoconium commune	Australia (80)
Dissoconium dekkeri	Australia (80) Thailand (80)

FUNGI	LOCATIONS AND PUBLICATIONS
Dissoconium eucalypti	Australia (75)
Dothiorella sp.	Brazil (156)
Drechslera halodes	India (260)
Drechslera hawaiiensis - (*Bipolaris hawaiiensis*)	Uruguay (24)
Elsinoe eucalypti	Brazil (156)
Elsinoe eucalypticola	Australia (44)
Elsinoe eucalyptorum	Australia (231)
Emericella nidulans	India (260)
Endothia gyrosa - (Amphilogia gyrosa)	Australia (178;250;267) Brazil (156)
Endothia sp.	Brazil (156)
Endothiella sp.	Brazil (156)
Epicoccum purpurascens - (*Epicoccum nigrum*)	Australia (178)Uruguay (23;24;25)
Erysiphe cichoracearum - (*Erysiphe cichoracearum* var. *cichoracearum*)	Brazil (156)
Erysiphe polyphaga - (*Golovinomyces orontii*)	Brazil (156)
Eucasphaeria capensis	South Africa (74)
Eupenicillium brefeldianum	Uruguay (24)
Eutypa spinosa	Tasmania (266)
Fairmaniella leprosa	Chile (254) Uruguay (24)
Falcocladium sphaeropedunculatum	Brazil (60)
Falcocladium thailandicum	Thailand (71)
Fenestella media	Tasmania (266)
Foliocryphia eucalypti	Australia (44)
Fomitopsis africana	Cameroon (160)
Fulvoflamma eucalypti	Spain (69)
Furcaspora eucalypti	Australia (74)
Fusarium anthophilum	Uruguay (25)
Fusarium graminearum	Ethiopia (99) South Africa (198) Uruguay (24;25)
Fusarium oxysporum	Uruguay (24)
Fusarium semitectum - (Fusarium incarnatum)	India (260)
Fusarium sp.	Australia (178) Brazil (156) China (45) Hong Kong (277)Japan (135) Uruguay (25)
Fuscophialis brasiliensis	India (260)
Fusculina eucalypti	Australia (231)
Fusicoccum andinum - (Neofusicoccum andinum)	Venezuela (277)

FUNGI	LOCATIONS AND PUBLICATIONS
Fusicoccum eucalypti - (Neofusicoccum mangiferae)	Uruguay (23;25)
Fusicoccum macroclavatum	Uruguay (179)
Fusicoccum ramosum	Australia (175)
Fusicoccum sp.	Japan (135)
Fusicoccum stromaticum	Venezuela (277)
Galerina physospora	Hawaii (104)
Geniculosporium sp.	Uruguay (24)
Geotrichum sp.	Brazil (156)
Gliomastix murorum var. *polychroma*	Brazil (156)
Gloeophyllum trabeum	Spain (27)
Gloeosporidina sp.	Australia (269)
Glomerella cingulata	Japan (135) Tanzania (189)
Gloniopsis argentinensis	Argentina (145)
Gloniopsis praelonga	Argentina (145) Portugal (42) Spain (42)
Graphium sp.	Australia (178)
Gyrothrix circinata	India (260)
Hainesia lythri	Australia (178)Brazil (156) New Zealand (40440) Uruguay (24;25)
Hansfordia ovalispora	India (260)
Harknessia eucalypti	Brazil (156) New Zealand (283) Australia (40)
Harknessia gibbosa	Australia(74)
Harknessia globosa	Chile (254)
Harknessia hawaiiensis	Madagascar (59) Tasmania (270)Uruguay (23;24)
Harknessia ipereniae	Australia(74)
Harknessia renispora	Uruguay(23)
Harknessia sp.	Australia (263;267) Uganda (199)
Harknessia tasmaniensis	Tasmania (270)
Harknessia ventricosa	India (260)
Harknessia victoriae	Tasmania (270)
Harpographium sp.	Brazil (156)
Helicoma olivaceum	Japan (135)
Helicosporium serpentinum - (*Drepanospora pannosa*)	India (260)
Helicoubisia coronata	India (260)
Hemimycena crispula	Spain (138)

FUNGI	LOCATIONS AND PUBLICATIONS
Henicospora coronata	Samoa (155)
Heteroconium eucalypti	Uruguay (70)
Heteroconium kleinziense	South Africa (74)
Hohenbuehelia grisea - (*Hohenbuehelia atrocoerulea* var. *grisea*)	Spain (138)
Holocryphia eucalypti	Australia (109;111;113) South Africa (109;111) Uganda (195)
Hyphodiscosia jaipurensis	India (260)
Hypochnicium eichleri	Hawaii (104)
Hypoxylon sp.	Brazil (156)
Janetia euphorbiae	India (260)
Karstenula ceanothi	Tasmania (266)
Khuskia oryzae	Uruguay (25)
Kionochaeta spissa	Kenya (77)
Kirramyces corymbiae	Australia (256)
Kirramyces destructans - (*Phaeophleospora destructans*)	Indonesia (256) China (276)
Kirramyces epicoccoides	Madagascar (59)
Kirramyces viscidus	Australia (10;77)
Kirramyces zuluensis	China (276)
Kramasamuha sibika	India (260)
Lasiodiplodia crassispora	Uruguay (179) Venezuela (9;20;30;84)
Lasiodiplodia pseudotheobromae	Uruguay (179)
Lasiodiplodia rubropurpurea	Australia (9;20;30;84;181;185) Uruguay (179)
Lasiodiplodia theobromae	Brazil (156) Congo, Republic of the (197) India (260)Uganda (199) Venezuela (158;159)
Lecanostictopsis eucalypti	India (82)
Lembosina eucalypti	Australia (219)
Leptographium eucalyptophilum	Congo, Republic of the (125)
Leptomelanconium australiense	New Zealand (284)
Leptoxyphium madagascariense	Madagascar (44)
Leptosphaeria eustoma - (Phaeosphaeria eustoma)	India (260)
Leptospora rubella	Colombia (69)
Lopharia spadicea	Spain (27)
Lophodermium eucalypti	Tasmania (126)
Macbrideola scintillans	India (260)

FUNGI	LOCATIONS AND PUBLICATIONS
Macrohilum eucalypti	New Zealand (699)
Macrophomina phaseoli - (*Macrophomina phaseolina*)	China (45)
Macrophomina phaseolina	Japan (135)
Macrophomina sp.	Brazil (156)
Microdochium caespitosum	India (260)
Microsphaeropsis olivacea	Uruguay (23)
Microsphaeropsis pseudaspera	Uruguay (23)
Microthia havanensis	Cuba (109;111) Florida (109;111) Hawaii (109;111) Mexico (109;111)
Microthyrium eucalypticola	Myanmar (235)
Monocillium sp.	Brazil (156)
Monodictys cerebriformis	China (274;275)
Monodictys levis	India (260)
Monostichella robergei	New Zealand (279)
Mycosphaerella acaciigena	Australia (75) Venezuela (75)
Mycosphaerella africana	Colombia (58;82) Portugal (57;82) South Africa (56; 57;82; 91; 102;120; 137;224) Zambia (57;82)
Mycosphaerella ambiphylla	Australia (120;153)
Mycosphaerella ambiphyllus	Australia (152)
Mycosphaerella associata	Australia (72)
Mycosphaerella aurantia	Australia (120;137;152;153)
Mycosphaerella citri	Viet Nam (153)
Mycosphaerella colombiensis	Colombia (82;120)Viet Nam (153)
Mycosphaerella communis	South Africa (120;137) Spain (76;120)
Mycosphaerella cryptica	Australia (36;82;124;136;153;178) Chile (82;120;254;260) India (260) New Zealand (82) Tasmania (36)
Mycosphaerella crystallina	South Africa (56;82;120)
Mycosphaerella davisoniellae	Australia(70)
Mycosphaerella delegatensis	Australia (82)Ethiopia (137)
Mycosphaerella dendritica	Australia(75)
Mycosphaerella didymelloides	Spain(82)
Mycosphaerella ellipsoidea	South Africa (56;82)
Mycosphaerella elongata	Venezue (75)

FUNGI	LOCATIONS AND PUBLICATIONS
Mycosphaerella endophytica	South Africa (82;120)
Mycosphaerella eucalypti	Australia (82)
Mycosphaerella eucalyptorum	Indonesia (70)
Mycosphaerella excentrica	Australia (75)
Mycosphaerella flexuosa	Colombia (82;102;120)
Mycosphaerella fori	Australia (153) South Africa (118;120)
Mycosphaerella gamsii	India (70)
Mycosphaerella gracilis	Indonesia (57;82;120)
Mycosphaerella grandis - (Mycosphaerella parva)	Chile(120)
Mycosphaerella gregaria	Australia (34;36;120;152;153)
Mycosphaerella heimii	Australia(80) Brazil (102) Colombia (80) Indonesia (57;75;82)Laos(43) Madagascar(43;59;82;102;120) Thailand (75)
Mycosphaerella heimioides	Indonesia (57;82;120)
Mycosphaerella intermedia	New Zealand (102;120)
Mycosphaerella irregulari	Thailand(43)
Mycosphaerella irregulariramosa	South Africa(57;82;120)
Mycosphaerella juvenis - (Mycosphaerella nubilosa)	Kenya (82;57) South Africa (56;82) Tanzania (57;82) Zambia (57;82)
Mycosphaerella keniensis	Kenya (82;120)
Mycosphaerella konae	Thailand (75;76) Colombia (80)
Mycosphaerella lateralis	Australia (151;153) Spain (137) South Africa (56;82;120;278) Zambia (57;82;120;278)
Mycosphaerella longibasalis	Colombia (82)
Mycosphaerella madeirae	Madeira Islands (102;120)
Mycosphaerella marksii	Australia (36;56;76;80;82;120;124;153) Ethiopia (102) Indonesia (57;82) South Africa(56;82;102;120) Tanzania (57)
Mycosphaerella mexicana	Australia (120;152;153) Mexico (82)
Mycosphaerella molleriana	California (82) Portugal (75;82;102;120) Tanzania (189) United Kingdom (127) United States (102;120)
Mycosphaerella nubilosa	Australia (36;136;153;120;102;178) Ethiopia (102) New Zealand (82) Portugal (122) Spain (122) South Africa (120;199;122) Tanzania (122)

FUNGI	LOCATIONS AND PUBLICATIONS
Mycosphaerella obscuris	Indonesia (31)Viet Nam (31)
Mycosphaerella ohnowa	Australia (75) South Africa (102;120)
Mycosphaerella parkii	Australia (102) Brazil (82;120) Colombia(82) Indonesia (57)
Mycosphaerella parkiiaffinis	Brazil (75)
Mycosphaerella parva	Australia (26;82;120;124;152;153) Chile (102) Ethiopia (102) South Africa (102;120)
Mycosphaerella perpendicularis	Colombia (70)
Mycosphaerella pluritubularis	Spain(70)
Mycosphaerella pseudafricana	Zambia(70)
Mycosphaerella pseudocryptica	New Zealand(70)
Mycosphaerella pseudoendophytica	KwaZulu-Nat (70) South Africa (70;137)
Mycosphaerella pseudomarksii	Thailand (43)
Mycosphaerella pseudosuberosa	Uruguay (70)
Mycosphaerella pseudovespa	Australia (37)
Mycosphaerella quasicercospora	Tanzania (70)
Mycosphaerella quasiparkii	Thailand (43)
Mycosphaerella readeriellophora	Spain (120)
Mycosphaerella scytalidii	Colombia (70)
Mycosphaerella secundaria	Brazil (70)
Mycosphaerella sp.	Australia (136) Brazil (156) Chile (254) China (276) Colombia(57) Ethiopia (99) Kenya (203) Malawi (203) Mozambique (203) Tanzania (203) Tasmania(36) Thailand (43) Uganda (199) Zambia (203)
Mycosphaerella sphaerulinae	Chile (65)
Mycosphaerella stramenti	Brazil (70)
Mycosphaerella stramenticola	Brazil (70)
Mycosphaerella suberosa	Australia (153) Brazil (36;82;120;153) Colombia (82) Indonesia (57;82)New Zealand (40440;120)
Mycosphaerella sumatrensis	Indonesia (70;137)
Mycosphaerella suttoniae - (Mycosphaerella suttonii)	Australia (63;82;153) Brazil (82) Indonesia (57)
Mycosphaerella suttonii	Indonesia(120)
Mycosphaerella swartii	Australia (82;120)

FUNGI	LOCATIONS AND PUBLICATIONS
Mycosphaerella tasmaniensis	Australia (17;136;153) Tasmania (36;63;82;120)
Mycosphaerella thailandica	Laos (43)Thailand (43;75)
Mycosphaerella toledana	Spain (120)
Mycosphaerella tumulosa	Australia (37)
Mycosphaerella verrucosiafricana	Indonesia (70)
Mycosphaerella vespa	Australia (35;36) Tasmania (36;120)
Mycosphaerella vietnamensis	Laos(43)
Mycosphaerella vietnamiensis	Thailand (43) Viet Nam (31)
Mycosphaerella walkeri	Australia (36;82) California (82) Chile (120;254)
Mycosphaerella yunnanensis	China (31)
Mycotribulus mirabilis	Thailand (205) India (169)
Mycovellosiella eucalypti - (Passalora eucalypti)	Brazil (82)
Nawawia malaysiana	Malaysia (78)
Nectricladiella infestans	Brazil (83)
Neocosmospora sp.	Brazil (156)
Neocosmospora vasinfecta - (Neocosmospora vasinfecta var. vasinfecta)	Brazil (156)
Neofabraea eucalypti	Australia (44)
Neofusicoccum andinum	Venezuela (159)
Neofusicoccum australe	Australia (233) Spain (13) Uruguay (179)
Neofusicoccum corticosae	Australia (96;231)
Neofusicoccum eucalypticola	Uruguay (179)
Neofusicoccum eucalyptorum	South Africa (159;253)Uruguay (179)
Neofusicoccum mediterraneum	Greece (73; 96)
Neofusicoccum parvum	Swaziland (159; 224)
Neofusicoccum ribis	Venezuela (159)
Neofusicoccum sp.	Uruguay (179)
Neoplaconema cymbiforme	Tasmania (265)
Nigrospora sacchari	Uruguay (24)
Nigrospora sp.	Australia(178)
Nigrospora sphaerica	India (260)Uruguay(23;24;25)
Oidium candicans	Canary Islands(22)
Oidium eucalypti	Brazil(156)
Oidium eucalypti-globuli	Japan (35)
Oidium sp.	Brazil(156) Germany (7)Japan(135)

FUNGI	LOCATIONS AND PUBLICATIONS
Oncopodium indicum	India(249)
Ophiodothella longispora	Australia(176)
Ophiostoma piceae	New Zealand (98)
Ophiostoma quercus	KwaZulu-Natal (85) South Africa (105;111;144) South Africa, South Africa, Mpumalanga (85)
Ophiostoma rostrocoronatum	New Zealand (98)
Ophiostoma setosum	New Zealand (98)
Ophiostoma sp.	South Africa (86)
Ophiostoma stenoceras	Colombia(86)New Zealand (3;98) South Africa (86) Uruguay(86)
Ophiostoma tsotsi	Malawi (106) South Africa (106)
Parasympodiella elongata	Australia(44)
Parasympodiella eucalypti	Venezuela(44)
Parasympodiella laxa	Venezuela(39) India(260)
Passalora eucalypti	Brazil (54)
Passalora eucalyptorum	Malaysia(54)
Passalora intermedia	Madagascar (81)
Passalora morrisii	Australia (54;82)
Passalora tasmaniensis	Australia(54)
Penicillium funiculosum	India(260)
Penicillium purpurogenum	Uruguay(24)
Penicillium sp.	Brazil(156)
Penicillium thomii	Brazil(156)
Penidiella eucalypti	Thailand(43)
Penidiella pseudotasmaniensis	Australia (80)
Penidiella tenuiramis	Australia(80) Tasmania(80)
Periconia byssoides	India(260)
Periconia circinata	Argentina(33)
Periconia hispidula	India(260)
Periconia lateralis	Argentina(33)
Periconia minutissima	Argentina(33)
Periconia tirupatiensis	Argentina(33)
Periconiella ilicis	India(260)
Peristomialis parilis	California(206)
Pestalotia dichaeta	Brazil (156)
Pestalotia disseminata	China(45)

FUNGI	LOCATIONS AND PUBLICATIONS
Pestalotia sp.	Brazil(156) Japan(135)
Pestalotia theae - (Pestalotiopsis theae)	India(260)
Pestalotiopsis disseminata	New Zealand(69) Hong Kong(147;277) Japan(135)
Pestalotiopsis guepinii	Uruguay (23;24;25)
Pestalotiopsis mangiferae	Hong Kong (147;277) Myanmar(236)
Pestalotiopsis neglecta	Australia(267)
Pestalotiopsis sp.	Australia(178) Colombia(69) Venezuela(241)
Pestalotiopsis theae	Myanmar (236)
Peyronellaea eucalyptica	Australia (15)
Phacidiella eucalypti	South Africa (74)
Phaeophleospora destructans	Indonesia(82)
Phaeophleospora epicoccoides	Argentina(54) Australia(54) Bhutan (54) Brazil(54) Colombia(54) Ethiopia(54) Hong Kong(54) India(54) Indonesia(54) Italy(54) Japan(54;135) Kenya(203) Madagascar(54) Myanmar(54) Malawi(54;203) Mozambique(203) New Zealand (54; 82;203) United States(54) Zambia(54; 203)
Phaeophleospora eucalypti	Argentina(54) Australia(54 ;82) Brazil(54) Congo(54) Ethiopia(99) New Zealand (54; 82) India(54) Italy(54) Nepal(54) Pakistan(54) Paraguay(54) Peru(54) Philippines(54) Taiwan (54) United States(54) Uganda(199)
Phaeophleospora lilianiae	Australia(82)
Phaeophleospora stonei	Australia(75; 77)
Phaeoramularia eucalyptorum - (Passalora eucalyptorum)	Malaysia(82)
Phaeoseptoria eucalypti - (Phaeophleospora epicoccoides)	Brazil (156) China(277) Hong Kong(147; 277) Myanmar (236)New Zealand(40440)
Phaeoseptoria sp.	Brazil(156)
Phaeothecoidea eucalypti	Australia(75)
Phaeothecoidea intermedia	Australia (80; 261)
Phaeothecoidea minutaspora	Australia (80; 261)
Phaeothyriolum microthyrioides	Australia(80)

FUNGI	LOCATIONS AND PUBLICATIONS
Phaeotrichoconis crotalariae	Australia(80)
Phanerochaete australis	Hawaii(104)
Phanerochaete sordida	Hawaii(104)
Phloeospora sp.	Brazil(156)
Phlogicylindrium eucalypti	Australia(72)
Phlogicylindrium eucalyptorum	Australia(28)
Phoma eucalyptica	Australia(28) China(45) New Zealand(28)
Phoma eucalyptidea	Ukraine(93)
Phoma eupyrena	Uruguay(25)
Phoma exigua - (Phoma exigua var. exigua)	New Zealand(98)
Phoma microchlamydospora	United Kingdom(14; 15)
Phoma multirostrata	Uruguay(23;24)
Phoma sorghina	Uruguay(24; 25)
Phoma sp.	Australia (267)
Phoma subnervisequa	China(45)
Phoma tropica	Uruguay(24)
Phomatospora macrospora	Tasmania(266)
Phomopsis arnoldiae	Uruguay(23;24;25)
Phomopsis eucalypti	Uruguay(25)
Phomopsis sp.	Brazil(23)
Phragmocephala sp.	India(260)
Phyllachora eucalypti - (Clypeophysalospora latitans)	Australia(176)
Phyllosticta eucalypti	India(6)Ukraine(93)
Phyllosticta sp.	Japan(135)
Pilidiella eucalyptorum	Australia (178;241) Brazil(241) Indonesia(241) Mexico(241) Viet Nam(241)
Pilidiella sp.	China(276)
Pisolithus tinctorius	Brazil(156)
Pithomyces chartarum	India(260)
Pithomyces sacchari	India(260)
Pleospora eucalypti	Kuwait(161)
Pleospora herbarum	Ukraine(93)
Pleospora sp.	Uruguay(23)
Pleurotheciopsis sp.	India(260)
Podosphaera pannosa	Argentina(90)

FUNGI	LOCATIONS AND PUBLICATIONS
Polydesmia fructicola	Spain(188)
Polydesmia turbinata	Spain(188)
Polyscytalina grisea	India(260)
Polyscytalum algarvense	Portugal(44)
Polyscytalum sp.	India (260)
Polystigma rubrum	Uruguay(23)
Pseudocercospora acerosa	New Zealand (286)
Pseudocercospora basiramifera	Thailand(82)
Pseudocercospora basitruncata	Colombia(82)
Pseudocercospora chiangmaiensis	Thailand(43)
Pseudocercospora crousii	New Zealand(268; 80)
Pseudocercospora cubae	Cuba(82)
Pseudocercospora deglupta	Malaysia (82) Papua New Guinea (29;82)
Pseudocercospora denticulata	Dominican Republic (82)Japan(82)
Pseudocercospora epispermogoniana	South Africa(56;82)
Pseudocercospora eucalypti - (Pseudocercospora paraguayensis)	China(112;140;277)
Pseudocercospora eucalypticola	India(216)
Pseudocercospora eucalyptigena	Australia(29)
Pseudocercospora eucalyptorum	Germany(82) Italy(82) Japan(135) Kenya(82) Madagascar(82;59) New Zealand(98) Portugal(82) South Africa(82)
Pseudocercospora flavomarginata	Thailand (121)
Pseudocercospora irregularis	Peru(82)
Pseudocercospora madagascariensis	Madagascar(82)
Pseudocercospora natalensis	South Africa(82)
Pseudocercospora norchiensis	Italy (75)
Pseudocercospora paraguayensis	Brazil(82) Israel(82) Thailand (287) Paraguay(82)
Pseudocercospora pseudoeucalyptorum	Australia (80) California(80) Portugal(80) South Africa(80) United Kingdom(80)
Pseudocercospora robusta	Malaysia(82)
Pseudocercospora schizolobii	Thailand(79;80)
Pseudocercospora sp.	Madagascar(80)
Pseudocercospora subulata	New Zealand(70;286) Tasmania(271)

FUNGI	LOCATIONS AND PUBLICATIONS
Pseudocercospora tereticornis	Australia(80)
Pseudofusicoccum adansoniae	Australia(175)
Pseudofusicoccum ardesiacum	Australia(175)
Pseudofusicoccum kimberleyense	Australia(175)
Pseudofusicoccum stromaticum	Venezuela(159;276)
Pseudomerulius curtisii	Hawai(103)
Ralstonia solanacearum (Bacteria)	China(276)
Ramularia eucalypti	Italy(75) Australia (75)
Readeriella angustia	Australia(80) Tasmania (80)
Readeriella callista	Australia(79;80)
Readeriella dendritica	Australia(79)
Readeriella eucalypti	Portugal (80;231) Spain(231)
Readeriella eucalyptigena	Australia(80)
Readeriella menaiensis	Australia(80)
Readeriella mirabilis	Australia(80; 77) New Zealand (283)Tasmania(80; 77)
Readeriella nontingens	Australia(80)
Readeriella novaezelandiae	New Zealand (77)
Readeriella patrickii	Australia(79) Tasmania(80)
Readeriella pseudocallista	Australia(80)
Readeriella tasmanica	Australia(80) Tasmania(80)
Rehmiodothis eucalypti	Australia(176)
Rehmiodothis inaequalis	Australia(176)
Rhinocladiella mansonii - (Exophiala mansonii)	India(260)
Sarcostroma arbuti	New Zealand (98)
Sarcostroma brevilatum	New Zealand (98)
Sarcostroma mahinapuense	New Zealand (98)
Satchmopsis brasiliensis	India (260)Venezuela (39)
Schizoparme straminea	South Africa (241)
Schizophyllum alneum	Brazil (156)
Schizopora flavipora	Hawaii(104)
Schizotrichella sp.	Brazil (156)
Scolecobasidiella tropicalis	India(260)
Scolecobasidium constrictum - (Ochroconis constricta)	India6)
Scolecobasidium humicola - (Ochroconis humicola)	India(260)

FUNGI	LOCATIONS AND PUBLICATIONS
Seimatosporium sp.	Myanmar(236)
Seiridium eucalypti	Australia(267) New Zealand (279)Tasmania(178)
Seiridium papillatum	Australia(267)
Selenophoma australiensis	Australia(44)
Selenophoma eucalypti	South Africa (58)
Selenophoma sp.	Australia(178)
Septoria eucalyptorum	India (70)
Septoria mortolensis	China(45)
Septoria provencialis	France(70)
Septoria sp.	Italy(75)
Septoria typica	New Zealand (279)
Sistotrema brinkmannii	Uruguay(23)
Spadicoides aggregata	India(260)
Spegazzinia tessarthra	India(260)
Speiropsis simplex	Cuba(38)
Sphaceloma tectificae	Australia(44)
Sphaeropsis eucalypti - (Dothiorella eucalypti)	Uruguay(23)
Sphaerulina eucalypti	Myanmar(237)
Sporendocladia foliicola	Cuba(38)
Sporidesmiella hyalosperma var. hyalosperma	Cuba(38)
Sporothrix cyanescens	Australia(229)
Sporothrix eucalypti	Brazil(5)Uruguay (25)
Sporothrix sp.	Brazil(156)
Sporothrix variecibatus	South Africa, Western Cape(193)
Stachybotrys kampalensis	India(260)
Stachybotrys sp.	Brazil(156)
Staninwardia breviuscula	Venezuela(241)
Staninwardia suttonii	Australia(231)
Staphylotrichum coccosporum	India(260)
Stemonitis virginiensis	India(260)
Stenella eucalypti	Australia(75)
Stenella pseudoparkii	Colombia(70)
Stenella xenoparkii	Indonesia(70)
Stigmina eucalypti	Australia(75; 82)
Stigmina eucalypticola	Australia(82)

FUNGI	LOCATIONS AND PUBLICATIONS
Stigmina eucalyptorum	Australia(82)
Stigmina hansfordii	Australia(82)
Stigmina robbenensis	South Africa (53;58; 82)
Stigmina sp.	Venezuela(241)
Strelitziana australiensis	Australia(44)
Subulicystidium longisporum	Hawaii (104)
Sydowia eucalypti	Australia(44) Portugal(44) South Africa, Cape Province(65)
Sympoventuria capensis	South Africa (74)
Syncephalastrum racemosum	India(260)
Teichospora hispida	Portugal (42)
Teratosphaeria alboconidia	Australia(80)
Teratosphaeria aurantia	Australia (11)
Teratosphaeria biformis	Australia (11)
Teratosphaeria complicata	Australia(80)
Teratosphaeria considenianae	Australia(80)
Teratosphaeria corymbiae	Australia(80)
Teratosphaeria cryptica	Australia(80)
Teratosphaeria destructans	Australia(80)
Teratosphaeria dimorpha	Australia(77)
Teratosphaeria eucalypti	Australia(80)
Teratosphaeria flexuosa	Colombia(77)
Teratosphaeria foliensis	Australia (11)
Teratosphaeria hortaea	Madagascar(81)
Teratosphaeria juvenalis	South Africa(77)
Teratosphaeria majorizuluensis	Australia(80)
Teratosphaeria micromaculata	Australia (11)
Teratosphaeria miniata	Australia(80)
Teratosphaeria molleriana	Portugal(80)
Teratosphaeria nubilosa	Australia(80) Portugal(80)South Africa(80)
Teratosphaeria ovata	Australia(77)
Teratosphaeria parva	Australia(76; 80)
Teratosphaeria profusa	Australia(80)
Teratosphaeria readeriellophora	Australia(77)
Teratosphaeria sp.	Australia(11; 80; 77)
Teratosphaeria stellenboschiana	France(79; 80)South Africa (79; 80)

FUNGI	LOCATIONS AND PUBLICATIONS
Teratosphaeria suberosa	Australia(80)
Teratosphaeria suttonii	Bolivia(77)Indonesia(80) Viet Nam(80)
Teratosphaeria toledana	Spain(77)
Teratosphaeria veloci	Australia(77)
Teratosphaeria verrucosa	South Africa (77)
Teratosphaeria viscidus	Australia(79;80)
Teratosphaeria xenocryptica	Chile(80)
Tetraploa aristata	India(260)
Therrya eucalypti	Tasmania(264)
Thielaviopsis ceramica	Malawi (114;232)
Thielaviopsis eucalypti	Australia(247)
Thielaviopsis paradoxa	Brazil(156)
Thyriopsis sphaerospora	Brazil(156) Chile(254)
Torrendiella eucalypti	Indonesia(69)
Torula herbarum	India(260)
Trichoderma harzianum	Australia(24) Hawaii(24) India(260)Uruguay(24)
Trichoderma koningii	Uruguay(25)
Trichoderma sp.	Australia(217)Brazil (156)
Trichosphaeria eucalypticola	Australia(108)
Trimmatostroma excentricum	Brazil (156)
Ulocladium chartarum	Uruguay(24)
Ustulina sp.	Australia(178)
Valsa brevispora	Congo, Republic of the (2)Venezuela(2)
Valsa ceratosperma	Brazil(156)
Valsa cinereostroma	Chile (2)
Valsa eucalypti	California(2) India(2)
Valsa eucalypticola	India(2)
Valsa eugeniae	Indonesia(2)
Valsa fabianae	Australia (2; 231)South Africa (2) Uganda(2)
Valsa myrtagena	Indonesia(2)
Valsa sp.	Brazil (156) South Africa (2) Republic of the Congo (179) Uganda(199)
Valsaria insitiva	Portugal(128)
Valsaria rubricosa	South Africa (128)
Vermisporium acutum	New Zealand (279)

FUNGI	LOCATIONS AND PUBLICATIONS
Vermisporium brevicentrum	New Zealand (279)
Vermisporium cylindrosporum	New Zealand (279)
Vermisporium eucalypti	New Zealand (279)
Verticicladium trifidum	India(260)
Verticillium albo-atrum	India(260)
Verticillium psalliotae	India(260)
Verticillium sp.	Brazil(156)
Verticillium tenuissimum - (Phaeostalagmus tenuissimus)	India(260)
Volutina concentrica	India(260)
Volvariella caesiotincta	Spain(138)
Wiesneriomyces javanicus - (Wiesneriomyces laurinus)	India(260)
Wuestneia campanulata	Tasmania (266)
Wuestneia epispora	Australia(163;167)
Wuestneia molokaiensis	Hawaii(40;55)
Xylaria apiculata	Brazil(156)
Xylaria sp.	Uruguay(23; 24; 25)
Xylaria striata	Mexico(207)
Xylocoremium sp.	Uruguay(23;24)
Zanclospora indica	India(260)
Zasmidium aerohyalinosporum	Australia (80)
Zasmidium citri	Thailand (80)
Zasmidium nabiacense	Australia (80)
Zeloasperisporium eucalyptorum	Australia(44)
Zugazaea agyrioides	Canary Islands (123)
Zygophiala jamaicensis	Japan (135)
Zygosporium gibbum	India (260)
Zythiostroma sp.	Australia (267)

Basidiomycetes

FUNGI	LOCATIONS AND PUBLICATIONS
Aleurodiscus mirabilis (*Acanthophysium mirabile*)	Hawaii (104)
Amethicium chrysocreas	Hawaii (104)
Amphinema byssoides	Hawaii (104)
Antrodia gossypina	Hawaii (104)
Arachnocrea sp.	India (260)
Armillaria fumosa	Australia (186)
Armillaria hinnulea	Australia (186)
Armillaria mellea	Tanzania (189)
Armillaria montagnei	Australia (187)
Armillaria sp.	Indonesia (48) Kenya (203;180)
Armillaria tabescens	France (46)
Armillariella tabescens - (*Armillaria tabescens*)	Japan (135)
Austrogautieria clelandii	New Zealand (98)
Basidiodendron eyrei	Hawaii (104)
Bjerkandera adusta	Uruguay (24)
Botryobasidium botryosum	Hawaii (104)
Botryobasidium candicans	Hawaii (104)
Ceriporia purpurea	Hawaii (104)
Ceriporiopsis subrufa	Hawaii (104)
Coniophora olivacea	Hawaii (103;104)
Crepidotus epibryus	Spain (138)
Crepidotus lundellii	Pakistan (4)
Crepidotus martinii	Brazil (212)
Crepidotus roseus var. boninensis	Hawaii (104)
Crepidotus uber	Hawaii (104)
Dendrophora albobadia	Hawaii (104)
Descomyces albus	New Zealand (98)
Diplomitoporus lindbladii	Hawaii (104)
Erythricium salmonicolor	Brazil (156) Ethiopia (99;100) South Africa (74;194)
Exidiopsis mucedinea	Hawaii (104)
Flavodon cervinogilvum	Hawaii (104)
Ganoderma applanatum	Japan (135)
Ganoderma australe	Hawaii (104)
Gymnopilus junonius	New Zealand (98)

FUNGI	LOCATIONS AND PUBLICATIONS
Haplotrichum curtisii	Hawaii(104)
Helicogloea lagerheimii	Hawaii (104)
Hohenbuehelia rickenii	Spain (138)
Hohenbuehelia silvana	Spain (138)
Hyphoderma cremeoalbum	Hawaii (104)
Hyphoderma crystallophorum	Hawaii (104)
Hyphoderma nudicephalum	Hawaii (104)
Hyphoderma pallidum	Hawaii (104)
Hyphoderma praetermissum	Spain (27) Hawaii (104)
Hyphoderma puberum	Hawaii (104)
Hyphoderma setigerum	Hawaii (104)
Hyphodontia arguta - (Grandinia arguta)	Hawaii (104)
Hyphodontia nespori	Hawaii (104)
Hypochnicium punctulatum	Hawaii (104)
Hypoderma medioburiense	Canary Islands (22)
Inonotus rheades	Brazil (156)
Junghuhnia vincta	New Zealand (98)
Laccaria laccata	New Zealand (98)
Laetiporus portentosus	New Zealand (98)
Laetiporus sulphureus	Brazil (156) Greece (272) Hawaii (104) Pakistan (4)
Marasmiellus omphaliiformis	Spain (138)
Megasporoporia cavernulosa	Hawaii (104)
Melanotus hepatochrous	Spain (138)
Memnoniella echinata	India (260)
Microporus flabelliformis	Hawaii (104)
Minimedusa obcoronata	Thailand (44)
Mycena papyracea	Hawaii (104)
Mycena tenerrima	Spain (138)
Mycoacia aurea	Hawaii (104)
Oligoporus caesius - (Postia caesia)	Hawaii (104)
Parmastomyces transmutans	Hawaii(104)
Paxillus curtisii - (Pseudomerulius curtisii)	Hawaii(104)
Paxillus panuoides - (Tapinella panuoides)	Hawaii(104)
Peniophora cinerea	Hawaii (104) Uruguay(25)
Peniophora lycii	Canary Islands (22)Uruguay(23)

FUNGI	LOCATIONS AND PUBLICATIONS
Peniophora sp.	Uruguay(23; 25)
Perenniporia japonica	Hawaii(104)
Perenniporia tephropora	Hawaii(104)
Phellinus gilvus	Hawaii(104)
Phellinus grenadensis	Hawaii(104)
Phellinus noxius	Japan(135)Taiwan(12;41)
Phlebia acanthocystis	Hawaii(104)
Phlebia hydnoidea	Hawaii(104)
Phlebiella tulasnelloidea	Hawaii(104)
Phlebiopsis peniophoroides	Hawaii(104)
Piloderma byssinum var. byssinum	Hawaii (104)
Pleuroflammula ragazziana	Spain (138)
Pluteus nanus	Spain (138)
Pluteus pellitus	Spain (138)
Pluteus phlebophorus	Spain (138)
Pluteus podospileus	Spain (138)
Pluteus umbrinellus	Spain (138)
Polyporus arcularius	Hawaii(104)
Psathyrella conopilus	Spain(138)
Psathyrella dicrani	Spain(138)
Psathyrella pennata	Spain(138)
Puccinia psidii	Brazil(115;156;178) Taiwan(52) Urugua(234)
Quambalaria cyanescens	Australia(87;177) Wales(172)
Quambalaria eucalypti	Australia (177) Brazil(178) South Africa(172;177;204;215) South Africa, KwaZulu-Natal (87) Uruguay(178)
Quambalaria pitereka	China (276)
Quambalaria pusilla	Thailand(215)
Quambalaria simpsonii	Thailand(44) Australia (44)
Resinicium bicolor	Hawaii(104)
Resupinatus applicatus	Hawaii(104)
Rhizoctonia solani	Brazil(156)
Rhizoctonia sp.	Brazil(156) China(45)
Rigidoporus microporus	Hawaii(104)
Rigidoporus vinctus - (Junghuhnia vincta)	Hawaii(104)
Royoporus badius	India(88)

FUNGI	LOCATIONS AND PUBLICATIONS
Scleroderma cepa	New Zealand (98)
Scopuloides rimosa - (Phanerochaete rimosa)	Hawaii (104)
Sebacina incrustans	Hawaii (104)
Skeletocutis lilacina	Hawaii(104)
Stereum ostrea	Hawaii(104)
Stereum sp.	Australia(178)
Thanatephorus cucumeris	Brazil(156)
Thelephora sp.	China (45)
Tinctoporellus epimiltinus	Hawaii(104)
Tomentella chlorina	Hawaii(104)
Tomentella rubiginosa	Portugal(116)
Trametes hirsuta	Hawaii(104)
Trametes versicolor	Hawaii(104) New Zealand (98)
Trechispora mollusca	Hawaii(104)
Tricholoma saponaceum	New Zealand (98)
Tubaria romagnesiana	Spain(138)
Tubulicium vermiferum	Hawaii (104)
Tubulicrinis calothrix	Hawaii (104)
Ustilago vriesiana	Portugal (173) Spain(173)
Vesiculomyces epitheloides	Hawaii(104)

Chytridiomycetes, Oomycetes and Zygomycota

FUNGI	LOCATIONS AND PUBLICATIONS
Mucor racemosus	India (260)
Mycotypha microspora	India (260)
Phytophthora alticola	Australia(95)South Africa(150)
Phytophthora cactorum	Australia(95) United States(95)
Phytophthora cambivora	Australia(95)
Phytophthora captiosa	New Zealand(26;92;285)
Phytophthora cinnamomi - (Phytophthora cinnamomi var. cinnamomi)	Australia(95;139) Brazil(156) New Zealand(98)
Phytophthora cinnamomi var. cinnamomi	Australia(95)
Phytophthora citricola	Australia(32; 95)
Phytophthora citrophthora	United States (95)

FUNGI	LOCATIONS AND PUBLICATIONS
Phytophthora cryptogea	Australia(95) Japan(95) Tasmania(95)
Phytophthora drechsleri	Australia(95)
Phytophthora fallax	New Zealand(26;92; 98)
Phytophthora frigida	South Africa (150)
Phytophthora heveae	Australia(95)
Phytophthora megasperma	Australia(95)
Phytophthora multivora	Australia(210) Washington (130)
Phytophthora nicotianae	Argentina (95) Australia(95) Brazil(95) Italy(95) South Africa(149)
Phytophthora parasitica - (Phytophthora nicotianae)	Brazil (95)
Phytophthora sp.	Brazil (156)
Pythium aquatile	New Zealand(98)
Pythium debaryanum	Japan(135)
Pythium deliense	India(157)
Pythium irregulare	New Zealand(98)
Pythium myriotylum	India(157)
Pythium sp.	Brazil(156) China(45)Japan(135)
Pythium spinosum	India(157)New Zealand (98)
Pythium splendens	New Zealand (98)
Pythium vexans	India(157)
Rhizopus stolonifer	India(260)
Sclerotium coffeicola	Brazil (156)
Sclerotium rolfsii	China(45)
Synchytrium macrosporum	Myanmar(238)

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