Biodiversity of Plant Pathogenic Fungi
in the Kerala part of the Western Ghats

(Final Report of the Project No. KFRI 375/01)

C. Mohanan

Forest Pathology Discipline
Forest Protection Division

K. Yesodharan

Forest Botany Discipline
Forest Ecology & Biodiversity Conservation Division

KFRI

Kerala Forest Research Institute
An Institution of Kerala State council for Science, Technology and Environment
Peechi 680 653 Kerala

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ABSTRACT OF THE PROJECT PROPOSAL

1. Project No. : KFRI/375/01
2. Project Title : Biodiversity of Plant Pathogenic Fungi in the Kerala part of the Western Ghats
3. Objectives:

    i. To undertake a comprehensive disease survey in natural forests, forest plantations and nurseries in the Kerala part of the Western Ghats and to document the fungal pathogens associated with various diseases of forestry species, their distribution, and economic significance.

    ii. To prepare an illustrated document on plant pathogenic fungi, their association and distribution in various forest ecosystems in this region.

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ABSTRACT

An extensive survey on plant pathogenic fungi in the Kerala part of the Western Ghats carried out during 2001-2004 revealed a rich flora of plant pathogenic fungi harboring the plants in different forest ecosystems. Pathogenic fungi are found widely distributed in moist deciduous, semi-evergreen, and evergreen forests and forest plantations. A total of 4101 fungal isolates were obtained from the disease specimens collected and processed from 237 study sites selected in different forest ecosystems. The fungal isolates fall under 102 fungal genera and 247 species. Of these, fungi belonging to the Hyphomycetes and Coelomycetes classes (Fungi Imperfecti) were the most predominant ones. Coelomycetes were represented by 36 genera and 84 species, while Hyphomycetes were represented by 28 genera and 85 species. Basidiomycetes were represented by 19 genera and 44 species and Ascomycetes were represented by 16 genera and 29 species. Oomycetes were represented by only one genus and two species and Agonomycetes (Mycelia sterilia) were represented by two genera and three species.

Of the 4101 fungal isolates obtained in the present study, 60 pathogenic fungi were given the status of new species. A total of 151 pathogenic fungi were found to be new records from the Western Ghats, while 104 pathogenic fungi are reported for the first time from India. Altogether 639 plant species belonging to 395 genera were found infected with the pathogenic fungi in various forest ecosystems. Of these, 175 plant species were found as new host records for different pathogens.

Among the 237 study sites which fall under 96 Forest Ranges surveyed, 109 sites belonging to the moist deciduous forests located in different parts of the Western Ghats, registered a maximum number of 164 pathogenic fungi (1237 isolates), which is about 30% of the total isolates of fungal pathogens obtained in the study. Representative study sites in 59 localities in semi-evergreen forests, falling in 36 Forest Ranges in the State, yielded 892 isolates belonging to 79 pathogenic fungal species. From evergreen forests including a *Myristica* swamp, 605 isolates belonging to 50 pathogenic fungal species were recorded. Exploration made in the wet evergreen forests yielded 582 isolates belonging to 16 pathogenic fungal species. From forest nurseries, 45 pathogenic fungal species were recorded as causing diseases in 154 host plant species. From the shola forests, 19 fungal species and from the dry deciduous forests, 16 fungal species were obtained. From forest plantations 106 pathogenic fungal species were recorded.

Among the different forest ecosystems studied, forest plantations supported a rich pathogenic fungal flora with plant - pathogenic fungal ratio as high as 1:14. In moist deciduous forests and semi-evergreen forests, the figures of plant - pathogenic fungal ratio are 1:3.1 and 1:3.48 respectively. Shola forests and wet evergreen forests registered comparatively low plant-pathogenic fungal ratio of 1:1.65 and 1:1.46 respectively. In forest nurseries, though, a large number of host plants (154) were found diseased with the fungal pathogens, the plant - pathogenic fungal ratio is only 1: 3.77. The incidence, spread and severity of diseases and also the distribution of pathogenic fungi in different forest ecosystems are influenced by various climatic and edaphic factors as well as pathogen-host interrelationships. Monoculture exotic plantations and disturbed natural stands support a large number of fungal pathogens. Disturbances caused by anthropogenic factors including forest fires seem to be the major contributing factors for incidence and spread of fungal diseases and thereby build-up of pathogenic fungal populations.

Biodiversity indices for plant pathogenic fungi in different forest ecosystems in the Western Ghats were worked out separately. Fungal species richness indices (Margalef's index and Menhinick's index) ranged from 2.5605 to 5.6652 and 4.0899 to 21.0853 respectively. Among the eight forest ecosystems studied, moist deciduous forests exhibited maximum fungal species richness. Fungal species diversity indices (Simpson's index and Shannon's index) were deduced for each forest ecosystem which ranged from 0.0228 to 0.1183 and 2.4482 to 1.1026 respectively. Among the forest ecosystems studied, maximum fungal species diversity was recorded in forest plantations followed by moist deciduous and semi evergreen forests.

Diseases affecting the plants in different ecosystems include foliage diseases, stem cankers, wilt, heart rot, root rot, etc. Foliage disease, including rust infections, powdery mildews and black mildews, account for 96% of the total fungal infections in the different forest ecosystems studied. The obligate parasite, rust fungi, caused 3.04% of the total fungal infection, while the figures for powdery mildews and black mildews were 0.43% and 2.65% respectively. Only 2.43% stem diseases were recorded in all the ecosystems studied, while root infection including wilt disease was 0.85%. The results show that Mitosporic fungi, which belong to 65 genera and 150 species are widely distributed in the different forest ecosystems and harbor the host substratum, mostly the foliage, for their growth and survival.

In forest nurseries, technological change in seedling production system brought out by the introduction of root trainers has had a major impact on incidence and spread of fungal diseases. In root trainer nurseries, as soil-free or soil less growing media are used and high input seedling management practices are followed, many of the seedling pathogens could be excluded from the nursery. The plant - pathogenic fungal ratio in forest nurseries is only 1: 3.8.

In forest plantations, eucalypts dominate the system and a single host species (*Eucalyptus tereticornis*) harbors more than 25 genera of pathogenic fungi. This is almost 25% of the total fungal genera encountered in the study. The recently introduced exotic plant, *Acacia mangium* also harbors 21 genera of pathogenic fungi, and was found severely affected with vascular wilt pathogen, *Fusarium solani* and root rot pathogen *Ganoderma lucidum.* The results show that exotic host species are more vulnerable to the indigenous fungal pathogens and the monoculture exotic plantations serve as reservoir of inoculum of different phyto-pathogenic fungi. *Cylindrocladium quinqueseptatum,* a virulent foliage pathogen of eucalypts was found associated with more than 25 different indigenous host species in wet evergreen, evergreen, semi-evergreen and moist deciduous forests, which reveals the adaptability as well as over dominance of the pathogen in different ecosystems**.** In the evergreen and wet ever green forests, though large number of fungal pathogens were found causing foliage infections, they are not probably making any serious damage to the ecosystems. Diversity of obligate parasites like rust fungi is found more in evergreen, wet evergreen and semi-evergreen forests.

With regard to the community and species composition, almost same fungal flora was observed in moist deciduous and semi-evergreen forests, and forest plantations, however, fungal species dominance and abundance occurred depending on the environmental conditions, level of disturbances as well as host plant status. Pathogenic fungi viz., *Aecidium, Alternaria, Bipolaris, Calonectria, Cercospora, Colletotrichum, Coniella, Corticium, Corynespora, Cryphonectria, Curvularia, Cylindrocladium, Cytospora, Fusarium, Glomerella, Guignardia, Hemileia, Mycosphaerella, Myrothecium, Pestalotiopsis, Phoma, Phomopsis, Phyllachora, Phyllosticta, Pseudocercospora, Puccinia, Septoria, Uredo,* and *Uromyces* are the most widely distributed and dominant ones in different forest ecosystems in the Western Ghats.

INTRODUCTION

The recorded forest area of the Kerala State, by legal status is 1.1223 million ha. The effective forest area in the State is estimated at 0.94 million ha, which constitutes 24.2% of the State's geographical area. Most of the forests in the State are natural and although nearly 150 years of conservancy and protection have improved their stocking to some degree, the overall density of these forests is by no means optimum. Dense forest (crown density above 40%) constitutes over 81% of the actual forest cover, the balance being largely open forest with a crown density of 10 to 40%. The extensive dispersion of forest over the State is accompanied by considerable richness and diversity in composition.

The various forest ecosystems support rich flora and fauna. However, there is no comprehensive account that would give a realistic estimate of the number of species and their bio-geographic distribution in the State. It is estimated that the flora of the Kerala part of the Western Ghats comprises as many as 3700 vascular plants. However, our knowledge on the diversity of lower plants including microorganisms is so inadequate, despite their economic, medicinal, industrial, and ecological potential. No serious efforts have ever been made to understand the taxonomy, ecology, distribution and productive potentials of such invaluable biological resources.

The generally accepted estimate of the number of species of fungi on earth is a conservative 1.5 million (Hawksworth, 1991,1993, 2001; Heywood, 1995). The estimate was derived by extrapolating both from data on known fungi from well-studied regions as well as data on well-studied fungi from plant hosts (Hawksworth, 1991). Estimates of the species numbers in each major fungal group corroborate this conclusion (Rossman, 1995). Even though, it is quite uncertain exactly how many fungal species are already known, it may be in the range of 72,000 (Hawksworth *et al*., 1995) to 100,000 (Rossman, 1995). This shows that we know as little as 5% species of fungi that exist.

From the Kerala part of the Western Ghats, so far, a total of 1200 fungal species have been recorded. If the vascular plant-fungi ratio of 1:6 (Hawksworth, 1991) is applied, there should be around 24,000 fungal species. If this estimate approximates to the real situation, it means, more than 95% of the fungal flora of the Western Ghats is yet to be made known.

Many biodiversity specialists are of the opinion that tropical forests are more species-rich than temperate forests; thus this may be true for fungi as well. However, this hypothesis has not been rigorously tested for fungi, although a few comprehensive studies have been undertaken that provide supportive evidence (Cannon and Hawksworth, 1995; Hawksworth, 1993). In exploring tropical regions for fungi, it is anticipated that the most widespread and common species in a site will tend to be found first. Most likely, such species have been collected before and have been described already. However, the longer the time spent on intensive exploration, the more are the species discovered.

The known 200,000 species of vascular plants continue to serve as the major reservoir of novel fungi. It has been estimated that there may be around 270,000 species of plant-pathogenic fungi in the tropics (Shivas and Hyde, 1997)! In the tropics, it is particularly difficult to ascertain patterns of species richness. Batista and coworkers (1995) recorded 3,340 fungi from Brazil associated with 523 plant species, equivalent to an average of 6.4 fungi per host plant studied. Such data were not collected for an analysis of species richness and are difficult to assess, because not all plants were studied and plant species without fungi were not listed.

Plant pathogenic fungi include a very large and heterogeneous group of organisms that occupy positions of great economic importance in agriculture, forestry and natural plant communities. More than 8000 species of fungi have been reported as causing diseases and disorders in plants. They show an enormous diversity in life-history strategies and the ways in which they interact with their hosts. These interactions range from species that establish perennial, systemic infection that castrate their hosts, to pathogens that kill their

hosts with considerable rapidity, to pathogens that form discrete lesions whose individual effects are very limited (Burdon, 1993). Many pathogenic fungi can survive for a long period of time on dead host tissue or saprophytically in soil; other relies entirely on living host cells for sustenance. Collectively, the pathogens can attack virtually any plant part, although, individually they may be highly specialized. As a consequence, the range of pathogens found on different hosts also shows considerable diversity that may be associated with the evolutionary history of their hosts (Clay, 1995) or ecological criteria like the host's architectural complexity or the extent of pathogen's natural range (Strong and Levin, 1979).

To know the role of pathogens in shaping the genetic structure of plant populations and communities requires an understanding of the pathogens' diversity, their origins, and the evolutionary interplay that occurs between pathogens and their hosts. As is common with most organisms, plant pathogenic fungi rely on the process of mutation and recombination as the ultimate source of genetically based variation. Within a species, gene flow between populations supplements these processes as propagules spread from one epidemiological area to another and from one deme to the next. Studies of a wide variety of fungal pathogens have highlighted the importance of some of the mechanisms behind these broad groupings as sources of diversity. Rarely, however, have these studies addressed the way in which these mechanisms intermesh to generate the overall variation encountered within a species.

Of the three broad sources of variation in plant pathogenic fungal populations, gene flow is perhaps the simplest, although its contribution to diversity may be underestimated. The process of migration leading to founding of new pathogen populations in areas in which they previously were absent has been recorded on many occasions (Sharma *et al*., 1985a; presence of *Cryphonectria cubensis* in eucalypt plantations in Kerala). However, where a pathogen population already exists, the recognition of such events tends to be restricted to instances that lead to obvious shifts in the genetic structure of the recipient deme. There are many examples of long distance gene flow that can make to the genotypic diversity of

populations. In fact, in at least some wild host-pathogen systems, extinction and recolonization events occur at noticeable frequencies (Boland, 1992; Burdon, 1993), suggesting that migration and subsequent gene flow play an important role in contributing to genotype diversity in pathogen populations. This is the case especially when pathogen populations are small, and simple mutation is unable to substitute for the advantages of sexual reproduction (Maynard, 1968). In plant pathogen, recombination occurs either through sexual reproduction or through a process of somatic hybridization, in which nuclear and cytoplasmic material may be exchanged. The extent to which mutation contributes to the effective diversity of populations is affected by the inherent rate of mutation, the ploidy level of the pathogen (haploid versus diploid or dikaryotic), the size of the pathogen population, and the selective advantage conferred by the mutant phenotype (Burdon, 1992).

Thus, interplay of selection, genetic drift, migration, and mutation has a major effect on the genetic structure and diversity of all plant pathogenic fungal populations. The relative role of these factors may change markedly between different pathogen-host associations, between stages in the epidemiological cycle, and between associations in man-made and natural ecosystems. Size of the pathogen population is the one of the important factors in this interactive process. This is the case especially for obligate pathogens for which the patchy distribution of natural host populations tends to result in fungal populations that show large amplitude in size, relatively local and frequent extinctions, and asynchrony in the dynamics of neighboring demes (Antonovics *et al.*, 1994).

Studies of natural pathogen populations show some of the potential diversifying consequences of this patchiness in natural pathogens are extremely limited. However, circumstantial evidence is available in local populations of fungal pathogens like *Cylindrocladium quinqueseptatum* parasiting a series of small populations of its hosts (*Eucalyptus tereticornis* and *E. grandis*) in the Western Ghats (Mohanan and Sharma, 1985b; Sharma and Mohanan, 1992b). Details of these populations show examples of

MATERIALS AND METHODS

Selection of study areas and sample plots

A reconnaissance survey was carried out in the natural stands and forest plantations throughout the Western Ghats in the State and a total of 237 study areas were selected in different forest ecosystems, wet evergreen forests, evergreen forests, shola forests, semi-evergreen forests, moist deciduous forests, dry deciduous forests, and forest plantations which fall under 96 Forest Ranges including Protected Areas (Appendix I; Fig.1). From each selected study area, three sample plots of 100 x 100 m were laid out employing line transect method.

Ten forest nurseries including Forest Central Nurseries at Kulathupuzha (8^0 54'N, 77^0 44' E), Chettikulam (10^0 22'N, 76^0 23'E), Valluvassery (11^0 18'N, 76^0 16'E) and Cheruvancherry (11^0 50'N, 75^0 41'E) were selected for the study (Appendix I). The disease survey was carried out during 2001-2004. The study areas were visited during wet (June-October) and dry period (December-May) and the nurseries were visited during the months of December - July in each year.

Assessment of diseases in forest stands and nurseries and collection of disease specimens

Disease assessment was made in nurseries, plantations and natural stands and severity of foliage infection was rated on a numerical scale (0-3) of disease severity index (0: no disease; 1: low infection up to 25% of foliage infected; 2: medium, 25-50% foliage infected and >10% defoliation; 3: severe, 50-75% or more foliage infection and > 25% defoliation). Disease severity of stem, bark and root diseases in forest plantations was rated on a numerical scale (0-3) of disease severity index. Disease symptoms were recorded on disease data sheet and disease specimens (leaf, bark, stem, root, fruit, seed)

considerable change in the occurrence and relative frequency of particular pathotype (Sharma and Mohanan, 1982a,b, 1990,1991a,b, 1992b).

Studies on pathogenic fungi and diseases of forest stands have been systematically and intensively carried out in developed countries (Brown and Davidson, 1968, Hepting, 1971). In India, Bakshi (195) initiated inventory of forest diseases during 1970s. In the Kerala part of the Western Ghats, Sharma and Mohanan initiated problem-oriented researches on prime forestry species like teak, eucalypts, etc. during 1980s and 1990s (Sharma and Mohanan, 1981, 1982a,b, 1992a,b; Sharma *et al*., 1984a,b,c,d,e; 1985a,b; Sharma and Sankaran, 1984), and Mohanan during 1990s (Mohanan, 1994a,b, 1995 a, b, c, 1997 a, b; Mohanan and Sharma, 1982,1984, 1985, 1986 a, b, 1987, 1989a,b, 1990, 1991, 1993, 1994). Epidemiological studies on major diseases in man-made forests and forest nurseries in the Western Ghats and their management have also been worked out to avoid catastrophe (Sharma and Mohanan, 1992; Mohanan, 1990, 2202). However, in natural stands, so far, no systematic inventory on phytopathogenic fungi, except on heart rot fungi (Mohanan, 1991) has been carried out. The present study was undertaken with the following objectives:

i. To undertake a comprehensive disease survey in natural forests, forest plantations and nurseries in the Kerala part of the Western Ghats and to document the fungal pathogens associated with various diseases of forestry species, their distribution, and economic significance.

ii. To prepare an illustrated document on plant pathogenic fungi, their association and distribution in various forest ecosystems in this region.

were collected in polythene bags separately, assigned a specimen number and transported to the laboratory.

Identification of host plants

Floral and foliar samples were collected from the host plants and identity of the host plant confirmed. If there was any uncertainty concerning the identity of the host plant, flowers, fruits and bark samples were also collected and the specimens referred to experts and identity established. Herbarium specimens were processed and appropriate labeling was done and KFRI (Path) Herb. No. assigned.

Isolation and identification of pathogenic fungi

Appropriate samples from the specimens were taken for isolation of the causal fungi. Isolation of the causal organisms was made on Potato dextrose agar medium (PDA) after surface sterilization with 0.01% mercuric chloride. Inoculated plates were incubated at 25 $\pm 2^{0}$ C. Isolates of fungal species retrieved from various host species were separated and identification up to species level made. Special culture media (Potato sucrose agar medium (PSA), Plant extract agar medium (PEA), Oat meal agar medium (OMA), Maize meal agar medium (MMA), Czapek Dox agar medium (CDA) and different techniques were employed for sporulating the non-sporulating isolates. For obtaining production of fructifications and sporulation of the fungi, sterilized leaves, preferably of the host plant were used as the substratum. Sterilized leaves of host plant were kept over the Petri plates containing 2% water agar and incubated for > 7 days. To study the detailed structure of fructifications of various pathogenic fungi (pycnidia, rust sori, perithecia, basidiocarp, etc.) appropriate specimens were selected and their sections cut. Free hand sections of the fresh materials were taken using double-edged razor blades. Dried herbarium specimens or lignified plant tissues were softened by wetting the materials with ethanol followed by soaking for 1- 48h, depending on the materials, either in water or in 2% aqueous solution of KOH. For taking sections (2-6 µm) of plant tissues containing fungal fructifications as

well as fructifications in culture medium, a freeze microtome (Minotome-Cryostat, IEC, USA) was also used. The sections of fructifications of various fungi were observed under Leitz Dialux –20 Microscope and photomicrographs were prepared. Identification of the fungi up to species level, as far as possible, was made based on their cultural and morphological characteristics. The fungal isolates which belong to possibly new taxa and hitherto unpublished were assigned species number as Sp.1, Sp.2, etc. for publication elsewhere. However, information on the cultural characteristics, morphological and pathological peculiarities are provided for all such fungi at appropriate places in the text. All the fungal isolates were pure cultured and assigned KFRI. Culture No. and maintained in the Microbial Culture Collection Facility at KFRI.

Pathogenicity trials

Pathogenicity of fungal isolates was tested using seedlings of the respective host plants raised in the glasshouse. As it is not practical to test all the fungi isolated to their respective host plants to establish the pathogenic status, only selected fungi (rarely encountered ones, new species and weak pathogens) were screened. Pathogenicity of the fungal isolates to the respective hosts was tested by using 3-6 month-old seedlings and spraying conidial suspension (2×10^3 conidia/ml of sterile water) of the respective fungus. Three to five seedlings of the respective host plants were inoculated and the inoculated seedlings were incubated in humidity chamber (>90% r.h, $26 \pm 2\ ^0$C with 12 h dark and light period). Disease symptoms developed in the host plants were recorded and fungus was re-isolated from the diseased host tissues and pathogenicity of the respective fungal species confirmed.

Biodiversity analyses

Numerical data on pathogenic fungi obtained from representative study plots under each forest ecosystem were pooled and Species richness indices (Margalef's index and Menhinick's index), Species diversity indices (Simpson's index and Shannon's index)

were worked out. The following equations were used for deducing the species diversity indices:

Simpson : $\lambda = \Sigma pi^2$

Pi is the proportion of the individuals (isolates) in the ith species. Proportional abundance is obtained by dividing the density, biomass or number of plots in which the fungus was observed by the total density, or observations.

$$D = \sum \frac{n_i (n_i - 1)}{N (N-1)}$$

n_i is the number of individuals (isolates) in the ith species, and N is the total number of isolates.

Shannon : $H' = \Sigma p_i \ln p_i$

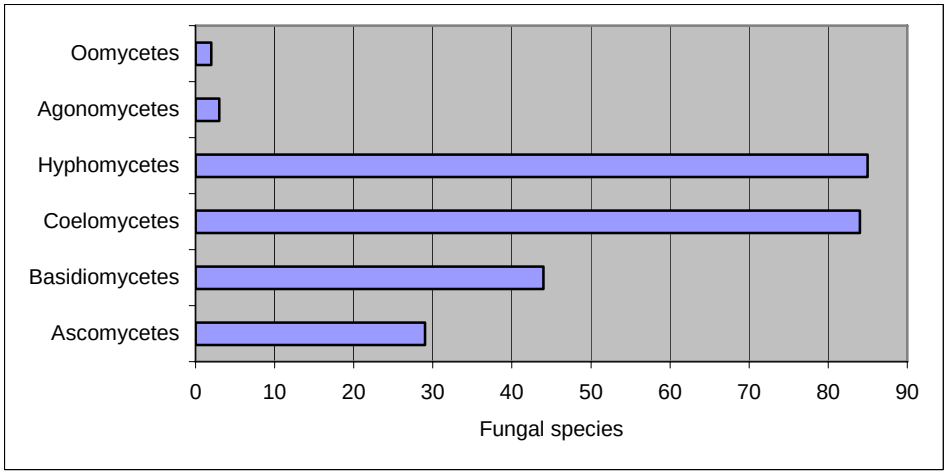
p_i (n_i / N) is the proportional abundance of the ith (each) species. In is the normal log (base e).

RESULTS AND DISCUSSION

An extensive survey on plant pathogenic fungi in different forest ecosystems in the Western Ghats, *viz*., moist-deciduous, semi-evergreen, evergreen and wet evergreen forests, shola forests, dry deciduous forests, forest plantations and forest nurseries conducted during 2001-2004 revealed a rich flora of plant pathogenic fungi harboring the plants and causing different diseases of various intensities.

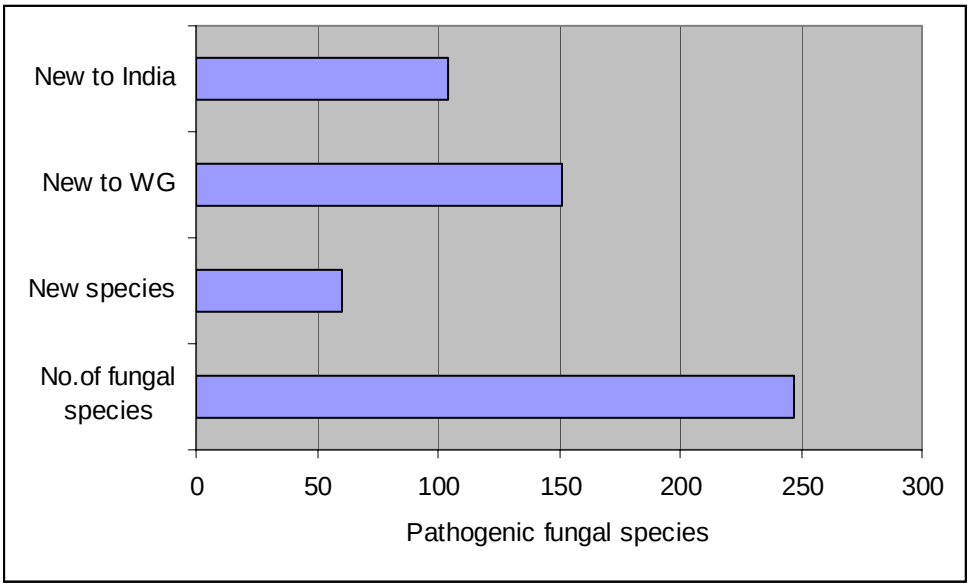
A total of 4101 fungal isolates were obtained from the disease specimens *viz*., foliage, stem, bark, root, fruit, seed, etc. collected and processed from 237 study sites selected in eight different forest ecosystems in the Western Ghats. The fungal isolates fall under 102 fungal genera and 247 species. Of these, fungi belong to the Hyphomycetes and Coelomycetes Classes (Fungi Imperfecti) were the most widespread and predominant ones. Coelomycetes are represented by 36 genera and 84 species, while Hyphomycetes are represented by 28 genera and 85 species. Basidiomycetes are represented by 19 genera and 44 species, while Ascomycetes represented by 16 genera and 29 species. Oomycetes are represented by only one genus and two species and Agonomycetes (Mycelia sterilia) represented by two genera and three species (Fig.2).

Fig.2: Plant pathogenic fungi belonging to different fungous classes recorded from the Western Ghats



Among 4101 fungal isolates obtained in the study, 60 fungal pathogens were given the status of new species. A total of 151 fungal pathogens were newly recorded from the Western Ghats and 104 fungal pathogens were reported for the first time from India (Fig.3). By following the existing practices in assigning new species status to a pathogenic fungi based on their association with particular host species/family, hundreds of new taxa can be erected from the isolates obtained in the present study. For example, a total of 608 isolates of *Phomopsis* were retrieved from 222 host plant species and treated here only as *Phomopsis* sp**.** Similarly, as more detailed taxonomic investigations are required to assign the status of new taxa, most of the new fungal isolates are treated here merely as species of the respective genus.

Fig. 3. Pathogenic fungi recorded from the Western Ghats and their status



Altogether 639 plant species belonging to 395 genera were found infected with the fungal pathogens in various forest ecosystems in the Western Ghats. Of these, 175 plant species were found as new host record for different pathogens. It is interesting to note that more than 26% of the plant species studied from different forest ecosystems were found new host record for different fungal pathogens.

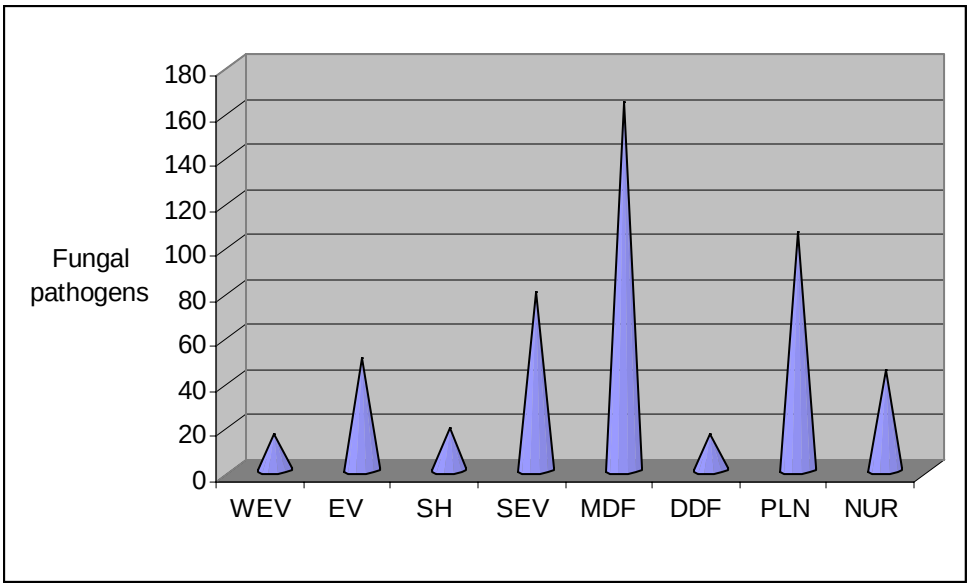
Among the 237 study sites surveyed, 109 sites belonging to the moist-deciduous forests located in different parts of the Western Ghats, recorded maximum number of 164 pathogenic fungi (1237 isolates) which is about 30.16% of the total isolates of fungal pathogens obtained in the study (Table 2). Representative study sites in 59 localities in semi-evergreen forests, falling in 36 Forest Ranges in the State, yielded 79 pathogenic fungi (892 isolates) which is about 21.75% of the total fungal isolates retrieved from the disease specimens collected and processed. In the evergreen forests, including a *Myristica* swamp in the Western Ghats, a total of 605 isolates of 50 pathogenic fungi were found associated with the ecosystems. Interestingly, exploration made from two sample plots in the wet evergreen forests yielded 16 phyto-pathogenic fungi. From the survey conducted in 10 forest nurseries (root trainer nurseries and conventional nurseries), 582 isolates belonging to 45 pathogenic fungi were isolated from seedling of 154 plant species. From the shola forests (6 study sites), altogether 19 pathogenic fungi and from the dry deciduous forests, 16 pathogenic fungi were obtained. Study sites in 19 forest plantations selected in different Forest Divisions in the Western Ghats recorded a total of 546 fungal isolates belonging to 106 pathogenic fungi which is about 18.97% of the total fungal isolates obtained in the study (Table 1; Fig.4). Thus, a total of 247 fungal pathogens belonging to 102 fungal genera were found causing diseases in different forest ecosystems. Some pathogens were found common in most of the forest ecosystems, while a few showed their restricted occurrence in certain forest ecosystems.

Table 1: Distribution of pathogenic fungi in different forest ecosystems

Sl.No.	Forest ecosystem	No. of study sites	No. of fungal pathogens recorded	No. of fungal isolates recorded	% to total
1	Wet evergreen forests	2	16	582	14.14
2	Evergreen forests	30	50	605	14.75
3	Shola forests	6	19	142	3.46
4	Semi evergreen forests	59	79	892	21.75
5	Moist-deciduous forests	109	164	1237	30.16
6	Dry deciduous forests	2	16	50	1.22
7	Forest plantations	19	106	546	0.133
8	Nurseries	10	45	582	14.19
	Total	237	247*	4101	100

* Many fungal pathogens are common to different ecosystems

Fig.4: Distribution of fungal pathogens in different forest ecosystems in the WG



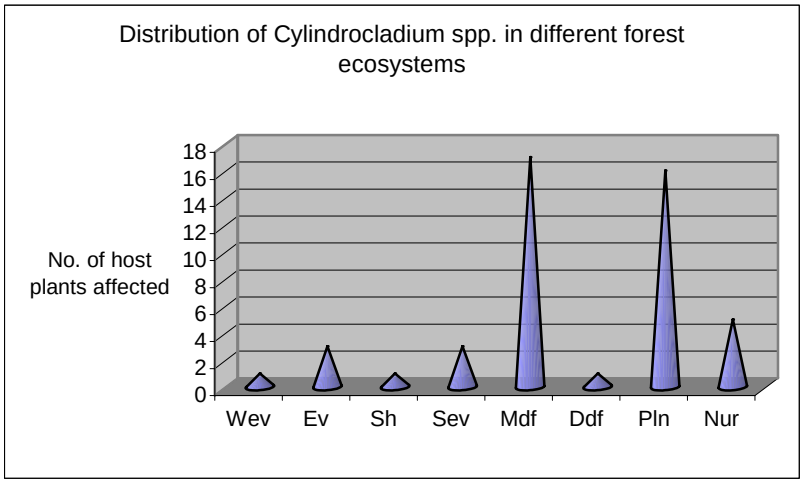
Among the different forest ecosystems studied, forest plantations support a rich pathogenic fungal flora and the plant - fungal ratio is 1:14.75. In moist deciduous forests and semi-evergreen forests, the plant-fungal ratio is 1:3.1 and 1:3.48 respectively. In shola forests (Meppadi shola, Mannavan shola, Pampadum shola, Old Devikulam Shola, Devimala shola and Eravikulam shola) and wet evergreen forests, the ratio is 1:1.65 and 1:1.46 respectively.

In forest nurseries, seedlings of a large number of host plant species (154) are found affected with 45 fungal pathogens; however, the plant-fungal ratio is only 1: 3.77 (Table 2). This is mainly because of the technological change in the seedling production system employing the root trainers, where only soil-less or soil free potting media (growing media) are used and there by most of the soil-borne nursery pathogens are excluded from the nursery.

In all the forest ecosystems, a few common fungal pathogens exhibited their predominance irrespective of the host species distribution, environmental conditions, as well as the level of disturbances caused. *Colletotrichum* and its teleomorph *Glomerella*

were found widely distributed and caused diseases in altogether 396 and 220 host species respectively in the Western Ghats. Nine species of *Cylindrocladium* were found causing diseases in different host plants and the fungal genus was found distributed in all the ecosystems studied (Fig. 5). Similarly, *Phomopsis* sp. was found widely distributed in the different ecosystems and caused foliage diseases in about 222 host species. The fungus was found widely distributed in the moist deciduous forests causing diseases in about 124 host plants (Fig. 6). Data on the selected major fungal pathogens are given in Figure 7.

Fig. 5: Distribution of *Cylindrocladium* in different forest ecosystems



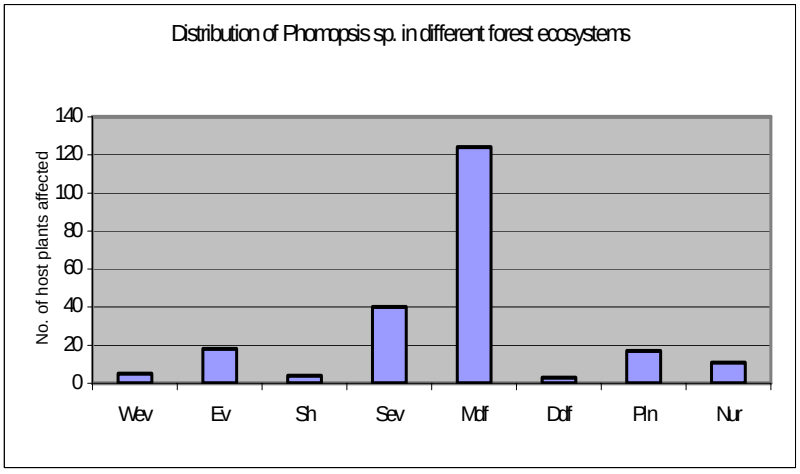
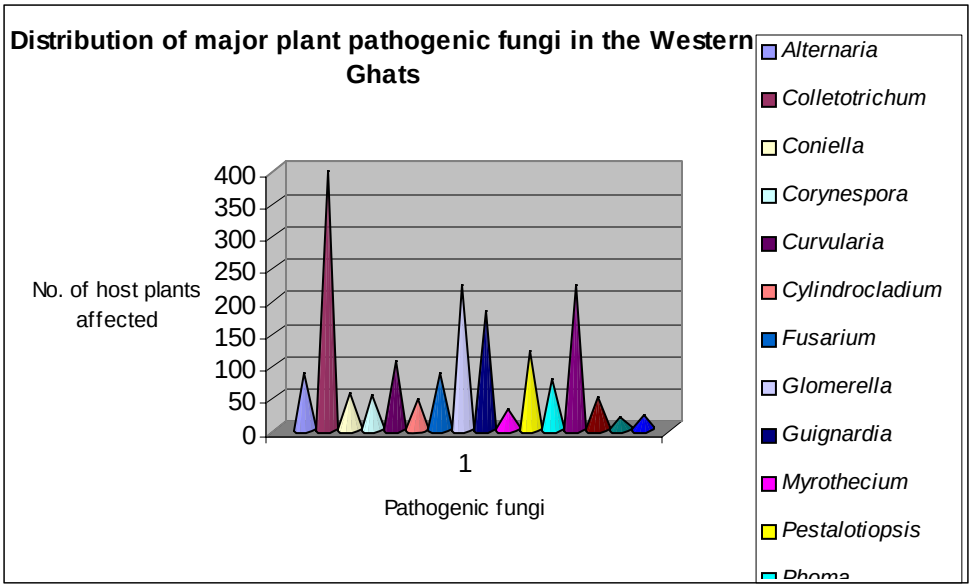


Fig.6: Distribution of *Phomopsis* sp. in different forest ecosystems in the Western Ghats

* Wev: wet evrgreen forests; Ev: evergreen forests; Sh: shola forests; Sev: semievergreen forests; Mdf: moist deciduous forests; Ddf: dry deciduous forests; Pln: plantations; Nur: nurseries

Fig. 7. Distribution of major fungal pathogens in the Western Ghats



The distribution of pathogenic fungi in the forest ecosystems in the Western Ghats is largely depended on various climatic and edaphic factors as well as host pathogen interrelationship. Moreover, disturbances caused by anthropogenic factors also influence to a great extent in the build up of pathogen inoculum potential and thereby development and spread of disease(s) even to an epidemic proportion and also the distribution of the pathogenic fungi over a large extent of area.

Diseases affecting the plants in different ecosystems include foliage diseases, stem cankers, wilt, heart rot, root rot, etc. The foliage diseases include leaf spots, leaf blotches, leaf blight, powdery mildews, black mildews, and leaf rust. Among the diseases affecting the forest stands and nurseries, foliage diseases are the most predominant. Foliage disease, including rust infections, powdery mildews and black mildews, accounts for about 95.90% of the total fungal infections in the different forest ecosystems studied. The obligate parasite, rust fungi, caused 3.04% of the total fungal infection, while the figures for powdery mildews and black mildews are 0.43% and 2.65% respectively. Only 2.43% stem diseases were recorded in all the sample plots studied, while root infection including wilt disease was only 0.85%. The results show that Mitosporic fungi, which belong to 64

genera and 169 species are found widely distributed in the different forest ecosystems and harbor the host substratum, mostly the foliage, for their growth and survival.

Ecosystem specificity as well as host specificity was recorded in fungal pathogens and also periodicity in occurrence and spread of disease was noticed. Definite patterns of incidence of various fungal diseases in different host species could be observed during pre-monsoon, post-monsoon and during the dry period (February-April) in all the forest ecosystems investigated. In the case of evergreen and wet evergreen forests, the initial fungal colonizer remains round the year or a succession takes place by eliminating the initial colonizer or a large number of fungal pathogens co-existed and affect the same host substratum simultaneously. Pathogenic fungi recorded from different forest ecosystems and their status are given in Table 2.

Table 2: Pathogenic fungi recorded from the Western Ghats and their status

Sl. No.	Fungi	No. isolates made	No. of host plants affected	New spp.	New Host record	New record from WG	New record from India
1	*Aecidium meliosmae-myrianthae* Henn. & Shirai.	5	1	-	-	-	-
2	*Aecidium mori* Barclay	1	1	-	-	-	-
3	*Aecidium* Pers. sp. 1.	1	1	+	+	+	+
4	*Aecidium* Pers sp. 2.	1	1	+	+	+	+
5	*Aecidium* Pers sp. 3.	1	1	+	+	+	+
6	*Aecidium* Pers sp. 4.	1	1	+	+	+	+
7	*Aecidium* Pers sp. 5.	2	1	+	+	+	+
8	*Aecidium* Pers sp. 6.	1	1	+	+	+	+
9	*Aecidium* Pers sp. 7	1	1	+	+	+	+
10	*Aecidium* Pers sp. 8.	1	1	+	+	+	+
11	*Alternaria alternata* (Fries) Keissler	4	3	-	+	-	-
12	*Alternaria citri* Ellis & Pierce apud Pierce	5	5	-	+	+	-
13	*Alternaria* Nees ex Fr. Nees spp.	120	77	+	+	+	+
14	*Ascochyta dendrocalami* Mohanan	4	2	-	-	-	-
15	*Ascochyta* sp.1.	13	13	+	+	+	+
16	*Asperisporium pongamiae* (H. Syd.) Deighton	3	1	-	-	-	-
17	*Asterina jambolanae* Kar. & Maity	1	1	-	+	-	-
18	*Aulographina eucalypti* (Cooke & Massee) Arx & E. Mull.	3	2	-	+	+	+
19	*Balansia linearis* (Rehm.) Diehl.	2	2	-	-	-	-
20	*Bartalinia* Tassi sp.	2	2	-	-	-	-
21	*Beltrania rhombica* O. Penzig.	3	3	-	-	+	-
22	*Beltrania* sp.1.	8	7	+	+	+	+

23	*Beltraniella* sp.1.	3	3	+	+	+	+
24	*Beltraniopsis* sp.1.	4	4	+	+	+	+
25	*Bipolaris bambusae* Mohanan	2	1	-	-	-	-
26	*Bipolaris ellisii* (Danq.) Alcorn	4	4	-	-	-	-
27	*Bipolaris maydis* (Nishikado & Miyake) Shoem.	2	2	-	-	-	-
28	*Bipolaris spicifera* (Bainier) Subram.	4	4	-	+	-	-
29	*Bipolaris* sp.	4	4	+	+	+	+
30	*Botritis cinera* Pers. .	4	4	-	+	+	-
31	*Botryobasidium salmonicolor*(Berk.& Br.) Venkatnarayanan	4	4	-	-	-	-
32	*Botryosphaeria* Ces & de Not sp.	3	2	+	+	+	+
33	*Calonectria floridana* Sobers	2	2	-	-	-	-
34	*Calonectria ilicicola* Boedijn & Reitsam	3	3	-	-	-	-
35	*Calonectria theae* Loos	3	3	-	-	-	-
36	*Camptomeris albiziae* (Petch) Mason.	1	1	-	+	+	-
37	*Cercospora bombacina* T.S. & K. Ramakr.	1	1	-	+	+	-
38	*Cercospora mitragynae* Bhargava & Nath	2	2	-	+	+	-
39	*Cercospora rubi* Sacc.	1	1	-	+	+	-
40	*Cercospora scopariae* Thirum. & Lacy	1	1	-	-	+	-
41	*Cercospora terminaliae* Syd.	1	1	-	-	+	-
42	*Cercospora* sp.1	2	2	+	+	+	+
43	*Cerodothis aurea* Muthappa	2	2	-	-	-	-
44	*Cerotelium flacourtiae* (Mundk. & Thirum.) Cumm.	8	3	+	+	+	-
45	*Chaetomella raphigera* Swift	9	7	-	-	+	-
46	*Chaetospermum carneum* Tassi	2	2	-	-	-	-
47	*Chaetospermum gossypinum* (Atkinson) Nag Raj	1	1	-	+	+	+
48	*Chaetospermum* sp.1	5	4	+	+	+	+
49	*Cladosporium cladosporioides* (Fres.) De Vries	18	18	-	+	+	-
50	*Cladosporium herbarum* (Pers.)Link ex Gray	4	4	-	-	-	-
51	*Cladosporium* sp.1	16	16	+	-	-	-
52	*Coccodiella ochlandrae* Mohanan	3	3	-	-	-	-
53	*Colletotrichum acutatum* Simmonds	9	7	-	+	+	+
54	*Colletotrichum capsici* (Syd.) Butl. & Bisby	19	13	-	+	+	-
55	*Colletotrichum coccodes* (Waller.) Hughes	1	1	-	+	+	+
56	*Colletotrichum coffeanum* Noack	1	1	-	+	+	+
57	*Colletotrichum crassipes* (Speg.)Arx.	10	8	-	+	+	-
58	*Colletotrichum dematium* (Pers. Ex zFr.) Grov.	13	13	-	+	+	+
59	*Colletotrichum falcatum* Went.	4	4	-	+	+	+
60	*Colletotrichum gloeosporioides* (Penz.) Sacc.	427	187	-	+	-	-
61	*Colletotrichum lindemuthianum* (Sacc.& Magn.) Br. & Cav.	2	2	-	+	-	-
62	*Colletotrichum* Corda sp. 1.	4	4	+	+	+	+
63	*Colletotrichum* sp. 2.	3	3	+	+	+	+
64	*Colletotrichum* sp. 3.	3	3	+	+	+	+
65	*Colletotrichum* sp. 4.	2	2	+	+	+	+
66	*Colletotrichum* spp.	387	148	-	+	+	-
67	*Coniella australiensis* Petrak	2	2	-	+	-	-
68	*Coniella castaneicola* (Ell. & Ev.) Sutton	1	1	-	-	-	-
69	*Coniella fragariae* (Oudem) Sutton	79	31	-	+	-	+
70	*Coniella granati* (Sacc.) Petrak & Syd.	1	1	-	-	-	-
71	*Coniella minima* Sutton & Thaung apud Sutton	6	4	-	+	+	+

72	*Coniella petrakii* Sutton	5	3	-	+	+	+
73	*Coniella* spp.	17	13	-	+	+	+
74	*Corticium salmonicolor* Berk. & Br.	13	12	-	+	-	-
75	*Corynespora cassiicola* (Berk. & M.A. Curtis) Wei	31	31	-	+	-	-
76	*Corynespora citricola* M.b. Ellis	3	3	-	+	+	+
77	*Corynespora* sp.	20	20	+	+	+	+
78	*Crossospora premnae-tomentosae* Ramkr. & Soumini	1	1	-	-	+	-
79	*Cryphonectria cubensis* (Bruner) Hodges	2	1	-	-	-	-
80	*Cryphonectria gyrosa* (Berk & Br.) Sacc.	2	2	-	+	-	-
81	*Cryptosphaera mangiferae* Died.	1	1	-	-	+	+
82	*Cryptosporiopsis eucalypti* Sankaran & B. Sutton	2	2	-	-	-	-
83	*Cryptosporiopsis* sp.1	10	8	-	+	+	+
84	*Curvularia borrerae* (Viegas) M.B. Ellis	1	1	-	+	+	
85	*Curvularia clavata* Jain	1	1	-	+	+	+
86	*Curvularia eragrostidis* (P. Henn.) J.A. Mayer	1	1	-	+	+	+
87	*Curvularia leonensis* M.B. Ellis	1	1	-	+	+	+
88	*Curvularia lunata* (Wakker) Boedijn	23	19	-	+	-	-
89	*Curvularia lunata* var. *aeria* (Batista, Lima & vasconcelos) M.B. Ellis	2	2	-	+	-	-
90	*Curvularia ovoidea* (Hiroe & Watan.) Muntanola	2	2	-	+	+	-
91	*Curvularia pallescens* Boedijn	10	10-	-	+	-	-
92	*Curvularia senegalensis* (Speg.) Subram.	3	3	-	+	+	-
93	*Curvularia verruculosa* Tandon & Bilgrami ex. M.B. Ellis	1	1	-	+	+	-
94	*Curvularia* sp.1.	1	1	+	+	+	+
95	*Curvularia* spp.	66	64	+	+	+	+
96	*Cylindrocarpon* Wollenw. Sp.	1	1	-	-	-	-
97	*Cylindrocladium candelabrum* Viegas	1	1	-	+	+	+
98	*Cylindrocladium clavatum* Hodges & May	1	1	-	+	-	-
99	*Cylindrocladium colhounii* Peerally	3	3	-	+	-	-
100	*Cylindrocladium floridanum* Sobers & Seymour	9	9	-	+	-	-
101	*Cylindrocladium ilicicola* (Hawley) Boedijn & Reitsma	2	2	-	+	-	-
102	*Cylindrocladium ovatum* El-Gholl, Alfenas, Crous & Schubert	1	1	-	+	+	+
103	*Cylindrocladium quinqueseptatum* Boedijn & Reitsma	166	25	-	+	-	-
104	*Cylindrocladium scoparium* Morgan	2	2	-	+	-	-
105	*Cylindrocladium theae* (Petch) Subramanian	2	2	-	+	-	-
106	*Cytospora eucalypti* Sharma & Mohanan	3	3	-	-	-	-
107	*Cytospora eucalypticola* van der Westhuizen	4	3	-	-	+	-
108	*Cytospora* sp.1.	1	1	+	+	+	+
109	*Cytospora* sp.2.	1	1	+	+	+	+
110	*Dactylaria* Sacc. sp.	1	1	-	+	+	+
111	*Dasturella divina* (Syd.) Mundk. & Kheshwala	2	2	-	-	-	-
112	*Dendrophoma eucalypti* Mohanan	1	1	+	+	+	+
113	*Dothiorella acaciae* Mohanan	1	1	+	+	+	+
114	*Dothiorella* Sacc. sp.	2	2	+	+	+	+
115	*Drechslera* Ito sp.	4	4	+	+	+	+

116	*Drechslera* state of *Cochliobolus spicifer* Nelson	1	1	-	-	+	-
117	*Exobasidium vexans* Massee	1	1	-	-	-	-
118	*Exserohilum* sp. 1.	2	2	+	+	+	+
119	*Fairmaniella leprosa* (Fairm.) Petr. & Syd.	3	3	-	+	+	+
120	*Fomitopsis dochmius* (Berk. & Br.) Ryv.	2	2	-	-	-	-
121	*Fomitopsis palustris* (Berk. & Curt.)Gilbn. & Ryv.	3	3	-	-	+	-
122	*Fomitopsis rosea* (Alb. & Schw. Ex. Fr.) P. Karst.	1	1	-	-	-	-
123	*Fusariella* Sacc.	1	1	+	+	+	+
124	*Fusarium acuminatum* Ellis & Everhart	2	2	-	+	+	-
125	*Fusarium avenaceum* (Fr.) Sacc.	1	1	-	+	+	-
126	*Fusarium culmorum*(W.G. Smith) Sacc.	5	5	-	+	+	+
127	*Fusarium decemcellulare* Bri	4	4	-	+	-	-
128	*Fusarium equiseti* (Corda) Sacc.	9	9	-	+	-	-
129	*Fusarium fusarioides* (Frag. & Cif.) Booth	2	1	-	+	+	+
130	*Fusarium heterosporum* Nees ex Fr.	1	1	-	+	+	+
131	*Fusarium lateritium* Nees	2	2	-	+	-	-
132	*Fusarium moniliforme* Sheldon	5	5	-	+	-	-
133	*Fusarium moniliforme* var. *Subglutinans* Wollenw. & Reink.	2	2	-	+	-	-
134	*Fusarium oxysporum* Schlecht.	14	14	-	-	-	-
135	*Fusarium sambucinum* Fuckel	2	2	-	+	+	-
136	*Fusarium semitectum* Berk. & Rav.	18	16	-	+	-	-
137	*Fusarium solani* (Mart.) Sacc.	10	9	-	+	-	-
138	*Fusarium sporotrichoides* Sherb.	1	1	-	+	+	+
139	*Fusarium tricinctum* (Corda) Sacc.	1	1	-	+	+	-
140	*Fusarium* spp.	11	11	-	-	+	-
141	*Ganoderma applanatum* (Pers. ex S.F. Gray) Pat.	3	3	-	+	+	-
142	*Ganoderma lucidum* (W. Curt.) Fr.) Karst.	9	9	-	+	-	-
143	*Gleosporidinia* Petrak sp.	3	3	-	+	+	+
144	*Glomerella cingulata* (Stonem.) Spauld. & Schrenk.	613	218	-	+	-	-
145	*Glomerella tucumanenesis* (Speg.) Arx & Muller	2	2	-	+	+	+
146	*Guignardia citricarpa* Kiely	11	11	-	+	-	-
147	*Guignardia dioscoreae* A.K. Pande.	1	1	-	+	+	+
148	*Guignardia* spp.	388	169	-	+	-	-
149	*Helminthosporium* Link. sp.1.	2	2	-	-	-	-
150	*Hemileia holarrhenae* Syd.	10	1	-	-	+	-
151	*Hemileia vastatrix* Racib.	2	2	-	-	-	-
152	*Hemileia wrightiae* Racib.	1	1	-	-	+	-
153	*Lasiodiplodia theobromae* (Pat.) Griff. & Maubl.	75	75	-	-	-	-
154	*Macrovalseria megalospora* (Mont.) Sivan.	1	2	-	+	-	-
155	*Maravalia ichinocarpi* (Thirum.) Cumm.	1	1	-	-	+	-
156	*Marssonina* Magnus sp.	9	6	-	+	+	-
157	*Meliola ailanthii* Sharma, Mohanan & Florence	1	1	-	-	-	-
158	*Meliola* spp.	59	59	-	+	+	-
159	*Microsphaeropsis* Hohn. sp. 1.	1	1	+	+	+	+
160	*Microsphaeropsis* Hohn. sp. 2.	1	1	+	+	+	+
161	*Microsphaeropsis* Hohn. sp. 3.	8	3	+	+	+	+
162	*Microsphaeropsis* Hohn. sp.4.	1	1	+	+	+	+

163	*Mycosphaerella cryptica* Cook & Hansf.	1	1	-	-	+	+
164	*Mycosphaerella* Johanson sp.1.	8	7	+	+	+	+
165	*Mycotribulus* mirabilis Nag Raj & Kendrick.	8	5	+	+	+	+
166	*Mycovellosiella* sp. 1.	8	1	+	+	+	+
167	*Myrothecium gramineum* Lib.	4	4	-	+	+	-
168	*Myrothecium masonii* Tulloch	3	3	-	+	+	+
169	*Myrothecium roridum* Tode	19	13	-	+	-	-
170	*Myrothecium* sp. 1.	15	10	+	+	+	+
171	*Myrothecium* sp. 2	1	1	+	+	+	+
172	*Neomelanconium deightoni* Petrak	1	1	-	+	+	+
173	*Oidium* Link spp.	14	14	-	+	-	-
174	*Olivea tectonae* (T.S. & K. Ramakr.) Mulder	3	1	-	-	-	-
175	*Pestalotiopsis karstenii* (Saccardo & Sydow) Steyaert	1	1	-	+	+	+
176	*Pestalotiopsis macrospora* (Cesati) Steyaert	13	12	-	+	+	+
177	*Pestalotiopsis maculans* (Corda) Nag Raj	72	72	-	+	+	+
178	*Pestalotiopsis metasequoiae* (Gucsvicz) Nag Raj	2	2	-	+	+	+
179	*Pestalotiopsis palustris* Nag Raj	10	10	-	+	+	+
180	*Pestalotiopsis perseae* Nag Raj						
181	*Pestalotiopsis smilacis* (Schweinitz) Sutton	2	2	-	+	+	+
182	*Pestalotiopsis tecomicola* Nag Raj	6	6	-	+	+	+
183	*Pestalotiopsis uvicola* (Spegazzini) Bissett	14	14	-	+	+	+
184	*Phacidiopycnis* Potebnia sp.	12	11	-	+	+	+
185	*Phaeophleospora eucalypti* (Cooke & Massee) Crous	5	5	-	+	-	-
186	*Phaeoramularia* Muntanola sp.1	3	3	-	+	+	-
187	*Phellinus gilvus* (Schw.)Pat.	1	1	-	-	-	-
188	*Phoma cava* Schulz.	1	1	-	+	-	-
189	*Phoma eupyrena* Sacc.	2	2	-	+	+	-
190	*Phoma glomerata* (Cda) Wollenw. & Hochaf.	3	1	-	-	-	-
191	*Phoma herbarum* Westd.	2	2	-	+	-	-
192	*Phoma multirostrata* (Mathur *et al*.) Dorenbosch & Boerema	1	1	-	-	+	-
193	*Phoma nebulosa* Thum	1	1	-	+	+	-
194	*Phoma sorghina* (Sacc.) Boerma, Dorenbosch & van Kesteren	4	4	-	+	-	-
195	*Phoma* Sacc. spp.	88	65	-	-	-	-
196	*Phomopsis* (Sacc.) Sacc. spp.	608	222	-	+	-	-
197	*Phyllachora calamigena*	1	1	-	-	-	-
198	*Phyllachora dalbergiae* Niessl.	1	1	-	-	-	-
199	*Phyllachora* Nitschke ex Fuckel	6	4	+	+	+	+
200	*Phyllosticta* Pers. spp.	59	50	-	+	+	-
201	*Physalospora dalbergiae* Sharma & Mohanan	1	1	-	-	-	-
202	*Polynema* Leveille sp.	8	5	-	+	+	+
203	*Pseudocercospora ranjita* (Chaudhury) Deighton	1	1	-	-	-	-
204	*Pseudocercospora* Speg. spp.	24	18	-	+	-	-
205	*Pseudoepicoccum tectonae* Sharma and Mohanan	1	1	-	-	-	-
206	*Pseudorobillarda sojae* Uecker & Kulik	1	1	-	+	+	+
207	*Pseudorobillarda* sp.1	1	1	+	+	+	+
208	*Puccinia* Pers.sp.1.	1	1	-	+	+	-
209	*Puccinia* Pers. sp. 2.	1	1	+	+	+	+
210	*Puccinia* Pers. sp. 3.	1	1	+	+	+	+

211	*Puccinia* Pers. sp.4.	1	1	+	+	+	+
212	*Pullospora* Fraul & Schotter sp.1	8	8	-	+	+	+
213	*Pullospora macrospora* Nag Raj	1	1	-	+	+	+
214	*Pyrenochaeta* De Not sp.1.	2	2	+	+	+	+
215	*Pythium ultimum* Throw.	1	1	-	-	-	-
216	*Pythium* sp.	1	1	-	+	-	-
217	*Ravenelia emblicae* Syd.	1	1	-	-	+	-
218	*Ravenelia* Berk. sp. 1.	1	1	+	-	+	+
219	*Readeriella mirabilis* H.& P. Syd.	5	5	-	+	+	+
220	*Rhizoctonia bataticola* (Taub.) Butler	1	1	-	-	-	-
221	*Rhizoctonia solani* Kuhn.	27	21	-	+	-	-
222	*Roestelia* Rebent. sp.1.	1	1	-	-	+	+
223	*Sclerotium rolfsii* Sacc.	21	19	-	+	-	-
224	*Septoria cassicola* Kell & Swing	1	2	-	-	+	-
225	*Septoria grewiae* Sukapure & Thirum.	1	2	-	-	+	-
226	*Septoria* Sacc. sp.	10	12	+	+	+	+
227	*Staganopsora vitensis* Unam.	1	1	-	+	+	+
228	*Stagonopsora* (Sacc.) Sacc. sp.1.	1	1	+	+	+	+
229	*Stenocarpella macrospora* (Earle) Sutton	3	3	-	+	+	-
230	*Trichoconis* Clem. sp.1	1	1	-	-	+	-
231	*Trichosporum vesiculosum* Butler	2	1	-	-	-	-
232	*Uncinula tectonae* Salm.	1	1	-	-	-	-
233	*Uredo bombacis* Petch	2	2	-	-	-	-
234	*Uredo sissoo* Syd.	2	2	-	+	-	-
235	*Uredo terminaliae* P. Henn.	1	1	-	-	+	-
236	*Uredo* Pers. sp. 1.	1	1	+	+	+	+
237	*Uredo* Pers. sp. 2.	1	1	+	+	+	+
238	*Uredo* Pers. sp. 3.	1	1	+	+	+	+
239	*Uredo* Pers. sp.4.	1	1	+	+	+	
240	*Uredo* Pers. sp.5.	1	1	+	+	+	+
241	*Urohendersonia pongamiae* Nag Raj & Ponnappa	1	1	-	-	-	-
242	*Uromyces* (Link) Unger sp. 1.	1	1	+	+	+	+
243	*Uromyces* (Link) Unger sp.2.	2	2	+	+	+	+
244	*Valsa eucalypti* Cooke & Harkness	2	2	-	+	-	-
245	*Valsa eucalypticola* Sharma & Mohanan	1	1	-	+	-	-
246	*Verticillium* Nees sp.1.	9	9	+	+	+	+
247	*Zaghouania olea* (Butler) Cumm.	1	1	-	-	-	-
	Total	**4101**	**2244**	**60**	**175**	**151**	**104**

Biodiversity of plant pathogenic fungi in the Western Ghats

The forests of the Western Ghats exhibit considerable variation in floristic composition, physiognomy, life forms, etc. because of the climatic, edaphic, and physiographic variations. The forests in this region have been classified into seven major types which

are divided into 20 sub-types and many further sub-divisions depending upon the floristic composition. In the present study, eight forest ecosystems including forest nurseries were selected for investigating the fungal diversity.

Most fungi consist of filaments (hyphae) that increase in length by the deposition of cell wall material from a growing tip. As these tips expand and produce new growing points, a network of mycelium develops. Once established, fungal mycelia are capable of essentially unlimited growth and persistence. The mycelial nature of most fungi affects the definition and interpretations of fungal diversity and makes the protocols and assumptions used for estimating fungal biodiversity inherently different from those used for plants and animals. To understand the limitations associated with estimations of fungal biodiversity, one must consider methods for counting fungal units used for most macro-organisms.

The level of cellular aggregations that fulfills the criterion for fungi and other microorganisms, however, is not very clear. For example, isolates of a single species of fungus obtained from an infected leaf at spatially disjunctive locations in the foliage may represent the mycelium of a single individual or the mycelium of several individuals. As a result, counting individual fungal colonies on an isolation plate, whether the isolate was obtained from a 1 mm^2 piece of substratum does not represent the same information obtained from counting plants or insects that occur within a defined area. Thus, one cannot be sure if fungal isolates of a species from a single habitat have been obtained from one individual or from several individuals. Although, the latter situation is common, the former circumstance may also occur.

With these existing limitations, the present investigation focuses on the presence or absence of a particular fungal species within an ecosystem in order to assess some aspects of biodiversity. Species richness (Menhinick's index (R2), Margalef's index (R1)) and species diversity indices (Simpson's index, Shannon index (H')) of pathogenic fungi in these different ecosystems were worked out and an overall picture is given in Table 3.

Table 3: Species richness and diversity indices of pathogenic fungi in different forest ecosystems

Forest ecosystem	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon's index (H')
Wet evergreen forests	2.56205	4.094376	0.0850202429	2.448233
Evergreen forests	3.7909	9.618165	0.0559238797	3.269729
Shola forests	2.832354	4.728552	0.0626262626	2.68539
Semi evergreen forests	4.8225694	13.951025	0.0531891106	3.536353
Moist deciduous forests	4.307260	21.085314	0.0471795878	3.70955
Dry deciduous forests	2.404164	4.089955	0.1118367347	2.413801
Forest plantations	5.665242	17.697342	0.0228204041	4.102671
Forest nurseries	3.946762	9.039484	0.0578413834	3.200247

Species richness

Species richness is the most widely used parameter for evaluating aspects of fungal diversity. In fact, three kinds of species richness can be distinguished: (1) numerical species richness, (2) species density, and (3) total species richness (Hurlbert, 1971; Kempton, 1979; Brown, 1995; Rosenzweig, 1995). The cumulative number of species based on a series of samples from a habitat is the total species richness. It would appear that an unambiguous and straightforward index of total species richness, **S**, would be the cumulative numbers of unique species present in a series of samples. The magnitude of **S**, however, depends on the size, number, and dispersion of samples in a particular ecosystem. Indeed, three mathematical relations (Power, Exponential, and Logistic) have been championed in the literature to predict the way in which **S** increases with effort, *A* (number, area, or volume of samples). Unlike the Power and Exponential species-effort curves, the logistic relation predicts the **S,** eventually will reach a plateau or asymptote. The value of **S** at this asymptote is an accurate estimate of the true species richness of the domain of interest. However, given the dependence of **S** on collection effort and the fact that limited financial resources, personnel or logistic support often prevent the collection of samples sufficient to attain asymptote values, **S** is of limited value as a comparative

index. Consequently, a number of indices that are independent of the number of samples taken have been developed to estimate species richness. Those indices are based on the relationship between **S** and *n*, the total number of individuals in the collection of samples.

The two well-known species-richness indices, the Margalef index (1988) and Menhinick index (1964), make specific assumptions concerning the relationship between **S** and *n* (**S** = $k\, n^{0.5}$, where *k* is a constant). In the present study, both Margalef index and Menhinick index of species richness were worked out for each forest ecosystem, which ranged from 2.5605 to 5.665242 and 4.089955- 21.085314 respectively (Table 4). Among the eight forest ecosystems investigated, moist-deciduous forests and forest plantations exhibited maximum species richness and dry deciduous forests showed the least species richness value (Table 4).

Species diversity indices

Diversity is a measure of the complexity of structure in an ecological community. It comprises two distinct attributes: species richness and species evenness. Simpson (1949) proposed the first index of diversity used in ecology. The index varies from 0 to 1 and is referred to as dominance measure because it is influenced strongly by the abundance of the most common species. Originally Simpson's index (λ) was restricted to ecological units in which all members of the unit (in the present case community) could be enumerated. As it is impossible to count all members, Simpson developed an unbiased estimator (D) of diversity based on a sample of N individuals. In the current study, Simpson's index was worked out for each forest ecosystem which ranged from 0.0228204041 to 0.1118367347.

The Shannon index of diversity (H') (Shannon and Weaver, 1949) is currently the most popular index in community ecology. H' is a measure of the average degree of uncertainty in predicting the specific identity of an individual chosen at random from a collection of S species and N individuals. Average uncertainty will increases as the

number of species increases and as the distribution of individuals among species becomes more even. Ludwig and Reynolds (1988) emphasized the two properties of the index that make it popular. First H' = 0 if (and only if) the sample includes only a single species. Second, H' reaches its maximum only when all species are equally abundant. The magnitude of H' is usually between 1.5 and 3.5 and is rarely greater than 4.5 (Margalef, 1972). In the present study, Shannon index ranged from 2.448233 to 4.102671. Among the forest ecosystems studied, maximum fungal species diversity was observed in forest plantations followed by moist-deciduous forests and semi-evergreen forests. Dry deciduous forests exhibited least fungal species diversity (Table 4). A limitation of species diversity indices is that they compress the data to a single value that conveys little information about the abundance of the species in the ecological unit. Aspects of the diversity of fungal assemblages are based not only on species composition and richness, but also by evaluation of how abundances are partitioned among the component species. Common species like *Colletotrichum gloeosporioides, Glomerella cingulata, Phomopsis* sp. etc. exhibited their abundance in all the forest ecosystems studied, however, certain rare pathogenic species were also found in abundance in particular ecosystems which are highlighted in the following sections.

West coast tropical evergreen forests

(Wet evergreen and Evergreen forests)

This type of forests constituted the climax vegetation of the Kerala part of the Western Ghats, characterized by at least three tiers, the highest often attaining a height of 40-45 m. This forests occupy between 600 and 1100 m a.s.l. and prefer an annual rainfall of more than 2000 mm, temperature between 15 ^{0} and 30^{0} C and humidity between 70 and 100 per cent. The upper storey consists of *Artocarpus heterophyllus* Lam., *Bischofia javanica* Blume, *Canarium strictum* Roxb., *Cullenia exarillata* Robyns, *Drypetes elata* (Bedd.) Pax. & Hoffm., *Dysoxylum malabaricum* Bedd. ex Hiern, *Elaeocarpus tuberculatus* Roxb., *Holigarna arnottiana* Hook.f., *Holigarna grahamii* (Wight) Kurz, *Mesua ferrea* L., *Palaquium ellipticum* (Dalz.) Baill., *Persea macrantha* (Nees) Kosterm.,

Poeciloneuron indicum Bedd., *Polyalthia coffeoides* (Thw. ex Hook.f. & Thoms.) Hook.f. & Thoms., *Vateria macrocarpa* Guptha, etc.

The second storey is characterized by species like *Aglaia elaeagnoidea* (A. Juss.) Benth., *Baccaurea courtallensis* (Wight) Muell.-Arg., *Cinnamomum malabatrum* (Burm.f.) Blume, *Dimocarpus longan* Lour., *Elaeocarpus serratus* L., *Litsea wightiana* (Nees) Hook.f., *Meliosma pinnata* (Roxb.) Maxim., *Myristica dactyloides* non Gaertn., etc. These trees attain a height of 15 to 30 m. The third storey which is less than 15 m in height consists of small trees like *Agrostistachys meeboldii* Pax & Hoffm., *Jambosa munronii* (Wight) Walp., *Memecylon sisparense* Gamble, *Turpinia malabarica* Gamble, *Xanthophyllum flavescens* Roxb., etc. Profuse growth of shrubs like *Solanum surattense* Burm.f., *Thottia siliquosa* (Lam.) Ding Hou, *Psychotria* sp., *Moghania* sp., *Strobilanthes* spp., etc. occurs. Only a few monocot species like *Calamus thwaitesii* Becc. ex Becc. & Hook, *Calamus hookerianus* Becc., *Pandanus furcatus* Roxb., *Ochlandra travancorica* (Bedd.) Benth. ex Gamble, *O. ebracteata* Raizada & Chatterjee, *Oxytenanthera* sp., etc. occurs. Ground flora is composed of herbs like *Elettaria cardamomum* (L.) Maton, *Amorphophallus* sp., *Heckeria* sp., ferns, etc. Climbers like *Pothos scandens* L., *Piper* spp., *Caesalpinia bonduc* (L.) Roxb., S*milax* sp., etc. are common.

Ecologically, this type of forest is the most advanced stage with high floristic richness and provides much of the tangible and intangible benefits. These forests are the storehouse of many wild relatives of the cultivated plants. About 25 per cent of the total forests cover in the Kerala part of Western Ghats belongs to this category.

In the wet evergreen forests at Sirendri and Panthanthodu (Silent Valley National Park and Attapady Forest Range), periodic surveys revealed that only 39 plant species were found infected with 16 fungal pathogens. Fungal infections were found mostly on foliage including leaf spots, leaf blight, leaf blotches, leaf rust and black mildew disease. *Aecidium, Colletotrichum, Corynespora, Curvularia, Guignardia, Phoma, Phomopsis*, etc. are the important foliage pathogens.

In the wet evergreen forests, only 0.78 % of the total disease specimens collected from all the forest ecosystems was found infected with fungal pathogens. In other words, about 5% of the total plant host species collected from different forest ecosystems, harbors pathogenic fungi in the wet evergreen forests in the Western Ghats. Species richness indices (Menhinick's index and Margalef's index) show that when compared to other forest ecosystems studied, wet evergreen forests support least species richness of fungal pathogens. This is also true in the case of species diversity, where both Simpson's and Shannon indices also showed least values among the eight forest ecosystems studied (Table 4). Among the 16 pathogenic fungal pathogens encountered in this forest ecosystem, *Colletotrichum gloeosporioides, Colletotrichum* sp., *Phomopsis* sp. and *Guignardia* sp. were the most common and abundant ones (Table 5).

Table 4: Species richness and diversity indices of plant pathogenic fungi in the wet-evergreen forest ecosystems

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
2	2.56205	4.094376	0.0850202429	2.448233

Table 5: Fungal species abundance in the wet evergreen forests

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Colletotrichum gloeosporioides*	7	17.94
2	*Colletotrichum* sp.	6	15.38
3	*Phomopsis* sp.	5	12.82
4	*Guignardia* sp.	5	12.82
5	*Glomerella cingulata*	4	10.25

In the tropical evergreen forests, 30 study sites including one site in *Myristica* swamp forests, falling in 19 Forest Ranges were surveyed. About 226 plant species were found infected with 51 pathogenic fungi. As in the case of wet evergreen forests, foliage infection was the most predominant disease and 605 fungal isolates were retrieved from

the diseased portions of the specimens including leaf spots, leaf blight, leaf blotches, leaf rust and black mildew disease. Foliage rust infection was prevalent in this type of forests and accounted for 3.69% of the total foliage infection. *Aecidium, Colletotrichum, Corynespora, Coniella, Crossospora, Curvularia, Fusarium, Glomerella, Guignardia, Phoma, Phomopsis*, etc. are the important foliage pathogens. Stem disease including heart rot accounts for 2% of the total infection. In the evergreen forests, about 5.48% of the total diseased host samples from all the forest ecosystems were found infected with fungal pathogens. In other words, about 34.82% of the total plant host species collected from different forest ecosystems, harbors pathogenic fungi in the evergreen forests in the Western Ghats.

Pathogenic fungal species richness indices (Menhinick's index and Margalef's index) were found higher than the wet-evergreen forests, shola forests and dry deciduous forests (Table 6). Simpson's and Shannon species diversity indices also showed higher values than the wet evergreen forest, shola forest and dry deciduous forest ecosystems (Table 6). Among the 50 pathogenic fungal species encountered in this forest ecosystem, *Colletotrichum gloeosporioides, Glomerella cingulata, Colletotrichum* sp., *Phomopsis* sp. and *Guignardia* sp. were the most common and abundant ones (Table 7).

Table 6: Species richness and diversity indices of plant pathogenic fungi in the evergreen forest ecosystems

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
30	3.7909	9.618165	0.0559238797	3.269729

Table 7: Fungal species abundance in the evergreen forests

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Colletotrichum gloeosporioides*	24	13.25
2	*Glomerella cingulata*	19	10.49
3	*Phomopsis* sp.	18	9.94
4	*Guignardia* sp.	15	8.28
5	*Colletotrichum sp.*	15	8.28

Southern montane wet temperate forests (Shola forests)

This type of forests occurs in the upper reaches of the hills, especially on cliffs and sheltered folds above 1900 m.a.s.l. Southern montane wet temperate forests are also known as shola and are found in pockets supporting stunted trees, which seldom attain more than 10 m. The temperature is very low (10^0-15^0C) and the forests receive a very high rainfall (>4000 mm). The relative humidity is very high (80-100%). The altitude and high winds control the height growth of the trees. These forests are interspersed with rolling grasslands. The vegetation comprised of less number of tree species like *Elaeocarpus munronii* (Wight) Mast., *Gordonia obtusa* Wall.ex Wight & Arn., *Meliosma pinnata* (Roxb.) Maxim. ssp.*barbulata* (Cufod.) Beus., *Schefflera* sp., *Symplocos* sp., and many Lauraceous and Myrtaceous members. *Strobilanthes* species forms the main under storey. The shola forests constitute only 0.2 % of the total area of the State and play an important role in the hydrological cycle.

In shola forests, six study sites falling in five Forest Ranges were surveyed and 45 plant species were found infected with 19 fungal pathogens. Mostly foliage infection was recorded from the shola forests and 142 fungal isolates of different fungi were found associated with foliage diseases including leaf spots, leaf blight, leaf blotches, leaf rust and black mildew disease. *Aecidium, Alternarira, Colletotrichum, Corynespora, Curvularia, Guignardia, Meliola, Pestalotipsis, Phoma, Phyllosticta, Phomopsis, Puccinia, Uromyces*, etc. are the common foliage pathogens. *Colletotrichum gloeosporioides, Glomerella cingulata, Meliola* sp. were the most abundant fungal pathogens in this forest ecosystem (Table 9). Pathogenic fungal species richness and species diversity indices are found comparatively higher than those recorded for the wet evergreen forest and dry deciduous forest ecosystems (Table 8).

Table 8: Species richness and diversity indices of plant pathogenic fungi in the shola forests

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
6	2.832353	4.728552	0.06262626	2.68539

Table 9: Fungal species abundance in the shola forests

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Colletotrichum gloeosporioides*	6	13.33
2	*Glomerella cingulata*	6	13.33
3	*Meliola* sp.	6	13.33
4	*Guignardia* sp.	3	6.66

West coast tropical semi-evergreen forests (Semi-evergreen forests)

This forest type is generally considered as a transitional stage between evergreen and moist deciduous forests. It is also found in localities where the evergreen forests are subjected to high disturbances. It occurs between 600 to 800 m.a.s.l. and in some places it extends up to 900 m.a.s.l. The floral composition is an admixture of both evergreen and deciduous species in the top storey. The prominent evergreen species are *Artocarpus heterophyllus* Lam., *Bischofia javanica* Blume, *Calophyllum polyanthum* Wall. ex Choisy, *Melicope lunu-ankenda* (Gaertn.) Hartley, *Mangifera indica* L., *Mesua ferrea* L., *Myristica dactyloides* non Gaertn., etc. The deciduous floral elements are *Acrocarpus fraxinifolius* Wight & Arn., *Bombax ceiba* DC., *Chukrasia tabularis* A.Juss., *Dalbergia latifolia* Roxb., *Grewia tiliifolia* Vahl, *Lagerstroemia microcarpa* Wight, *Pterospermum* sp., *Terminalia bellirica* (Gaertn.) Roxb., *Toona ciliata* Roem., etc.

The species occurring in the lower layer are almost the same seen in the evergreen forests. This forest type constituted about 11.40 per cent of the forest area of the State. This forest supports trees of more commercial value.

In the semi-evergreen forests, 59 study sites falling in 36 Forest Ranges were surveyed and the study revealed that 268 plant species were infected with fungal pathogens. Fungi causing foliage and stem diseases were recorded from these forests; 892 fungal isolates belonging to 79 fungal pathogens were found associated with the diseases. *Aecidium, Alternarira, Beltrania, Beltraniella, Colletotrichum, Corynespora, Coniella, Curvularia,*

Cylindrocladium, Guignardia, Meliola, Microsphaeropsis, Myrothecium, Mycosphaerella, Pestalotipsis, Phoma, Phyllosticta, Phomopsis, Puccinia, Uromyces, etc. are the important pathogenic fungi. *Fomitopsis*, *Phellinus*, etc. are the important heart rot fungi. In the semi-evergreen forests, about 6.44% of the total disease specimens collected from all the forest ecosystems were found infected with fungal pathogens. In other words, 41.46% of the total plant host species collected from different forest ecosystems, harbors pathogenic fungi in the semi-evergreen forests in the Western Ghats.

Pathogenic fungal species richness indices were found higher than those recorded for evergreen, wet-evergreen and shola forests. Also, species diversity indices were found high and reached very close to those recorded for the moist-deciduous forests (Table 10). Among the 79 fungal pathogens recorded in this forest ecosystem, *Phomopsis* sp. was found the most abundant species, followed by *Colletotrichum* spp. (Table 11).

Table 10: Species richness and diversity indices of plant pathogenic fungi in the semi-evergreen forests

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
59	4.825693	13.951025	0.0531891106	3.536353

Table 11: Fungal species abundance in the semi-evergreen forests

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Phomopsis* sp.	40	14.92
2	*Colletotrichum gloeosporioides*	27	10.07
3	*Glomerella cingulata*	24	8.95
4	*Guignardia* sp.	19	7.08
5	*Colletotrichum* sp.	17	6.34
6	*Curvularia* sp.	11	4.10

South Indian moist deciduous forests (Moist deciduous forests)

The trees in this type of forests reach 30 to 35 m in height. Compared to the evergreen forests, the plant species diversity is very poor. Buttressed trees are rare and fluting is common in species like *Xylia xylocarpa, Tectona grandis,* etc. Bamboos and reed bamboos are common. The differentiation into various layers is not very distinct. This type of forests thrives well at 200-1250 m a.s.l. The temperature regime is 20 ^{0}C- 35 ^{0}C. Relative humidity varies from 40-70 per cent. It prefers per annum rainfall between 1500 to 2500 mm. The principal species encountered are *Bombax ceiba* L., *Dalbergia latifolia* Roxb., *Grewia tiliifolia* Vahl, *Lagerstroemia microcarpa* Wight, *Schleichera oleosa* (Lour.) Oken, *Tectona grandis* L.f., *Terminalia paniculata* Roth, *Tetrameles nudiflora* R.Br., *Xylia xylocarpa* (Roxb.) Taub., etc. Giant lianas like *Spatholobus* sp, *Entada* sp etc. are very common. Common ground flora consists of many herbs, most which possess medicinal properties. These forests are in the seral stage in the succession towards climatic climax vegetation which is the wet evergreen forests. But due to successive fire incidence and anthropogenic disturbances, the forests have advanced towards the climax stage.

In moist deciduous forest, 109 study sites falling in 58 Forest Ranges were taken and the disease surveys revealed that 416 plant species were infected with 164 fungi. Foliage infections were the most predominant disease recorded from these forests; about 1237 fungal isolates were obtained from the disease specimens. Comparatively very severe foliage infection caused by rust fungi was observed in these forests. The rust infection accounts for 4% of the total foliage infections. *Aecidium, Alternarira, Beltrania, Beltraniella, Beltranipsis, Colletotrichum, Corynespora, Coniella, Curvularia, Cylindrocladium, Guignardia, Meliola, Microsphaeropsis, Myrothecium, Mycosphaerella, Pestalotipsis, Phoma, Phyllosticta, Phyllachora, Phomopsis, Puccinia, Ravenelia, Uredo, Uromyces,* etc. are the important pathogenic fungi. *Ganoderma, Fomitopsis, Phellinus,* etc. are the important heart rot fungi. In moist deciduous forests, 7.38% of the total disease specimens collected from all the forest ecosystems was found

infected with fungi. In other words, about 65.08% of the total plant host species collected from different forest ecosystems, harbors pathogenic fungi in the moist deciduous forests in the Western Ghats. Moist-deciduous forests registered maximum fungal species richness index (Margalef's index); fungal species diversity index (Shannon index) was found higher than the semi-evergreen forests and very close to the forest plantations (Table 12,13). *Glomerella cingulata, Phomopsis* sp., *Guignardia* sp., *Colletotrichum* sp., *Lasiodiplodia theobromae*, etc. were the most abundant fungi among the 164 pathogenic fungi recorded in this forest ecosystem (Table 13).

Table 12: Species richness and diversity indices of plant pathogenic fungi in the moist-deciduous forests

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
109	4.307259	21.085314	0.0471795878	3.70955

Table 13: Fungal species abundance in the moist-deciduous forests

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Glomerella cingulata*	135	10.98
2	*Phomopsis* sp.	124	10.08
3	*Guignardia* sp.	93	7.56
4	*Colletotrichum* sp.	87	7.07
5	*Colletotrichum gloeosporioides*	81	6.59
6	*Lasiodiplodia theobromae*	55	4.47
7	*Alternaria* sp.	52	4.23
8	*Pestalotiopsis maculans*	40	3.25
9	*Meliola* sp.	38	3.09
10	*Curvularia* sp.	38	3.09

Southern tropical dry deciduous forests (Dry deciduous forests)

This forest type is open with trees reaching 15 to 20 m. The presence of this type of forests in high elevation is mainly due to the aspect, low rainfall and frequent fires. This forests receive less rainfall (<1000 mm) and the temperature is very high (25^0-40^0C) with low atmospheric humidity (30-60%). The principal species in this type of forests are

Acacia sp., *Anogeissus latifolia* (Roxb. DC.) Wall.ex Guill. & Perr., *Bauhinia* sp., *Cleistanthus collinus* Benth., *Grewia tiliifolia* Vahl, *Pavetta indica* L., *Pterocarpus marsupium* Roxb., *Radermachera xylocarpa* (Roxb.) K.Schum., *Santalum album* L., *Tectona grandis* L.f., etc. The lower storey is comprised of *Cycas circinalis* L., *Holarrhena pubescens* (Buch.-Ham.) Wall.ex G. Don, *Wrightia tinctoria* (Roxb.) R.Br., etc. *Dioscorea* sp. and *Ichnocarpus frutescens* (L.) R.Br. are the common climbers. Many annual herbs make their appearance during rainy season.

Disease survey carried out in dry deciduous forests (2 study sites) in Chinnar Wildlife Sanctuary, 25 plant species were found infected with 50 fungal isolates belonging to 16 fungal pathogens. Only foliage infection was recorded from these study sites. *Alternaria, Colletotrichum, Curvularia, Phoma, Phomopsis, Pestalotiopsis, Phyllachora, Uromyces, Uredo*, etc. are the important foliage pathogens. In dry deciduous forests, of the total disease specimens from all the forest ecosystems, 0.60% was found infected with fungal pathogens. Among the eight forest ecosystems studied, dry deciduous forests registered the lowest fungal species richness indices as well as fungal species diversity indices (Table 14). Among the 16 pathogenic fungi, *Colletotrichum* sp. was the most abundant pathogenic fungus in this ecosystem.

Table 14: Species richness and diversity indices of plant pathogenic fungi in the dry deciduous forests

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
2	2.404163	4.089955	0.1118367347	2.413801

Forest plantations

Plantations of different forestry species have been raised through out the State. *Tectona grandis* L.f., *Eucalyptus tereticornis* Smith, *Eucalyptus grandis* Hill ex Maiden, *Eucalyptus regnans* Muell., *Eucalyptus globulus* Labill., *Bombax ceiba* L., *Ceiba*

pentandra (L.) Gaertn., *Ailanthus triphysa* (Dennst.) Alston, *Gmelina arborea* Roxb., *Hevea braziliensis* (Willd.ex A. Juss.) Muell.-Arg, *Elaeis guinensis* Jacq., *Acacia auriculiformis* A. Cunn.ex Benth., *Acacia aulacocarpa* Cunn.ex Benth., *Acacia mangium* Willd., *Swietenia macrophylla* King, etc. are the important species raised in plantations. Among these, teak, eucalypts and acacias are raised extensively.

Survey carried out in forest plantations (19 study sites) situated in 19 Forest Ranges in the Western Ghats, showed 37 plant species infected with 106 fungi; about 546 fungal isolates belonging to 106 fungi were retrieved from this forest ecosystem. Almost all the plant species raised in forest plantations were found affected with one or the other pathogenic fungi. Fungi causing foliage diseases were very common in this forest ecosystem, and account for 88.88% of the total fungal isolates obtained from the disease specimens from all the forest ecosystems. *Aecidium, Alternarira, Beltrania, Beltraniella, Beltraniopsis, Bipolaris, Exserohilum, Cercospora, Colletotrichum, Corynespora, Coniella, Curvularia, Cylindrocladium, Guignardia, Meliola, Microsphaeropsis, Myrothecium, Mycosphaerella, Pestalotiopsis, Phoma, Phyllosticta, Phyllachora, Phomopsis, Uredo, Uromyces,* etc. are the important pathogenic fungi. Stem diseases (stem canker and blight) caused by *Corticium salmonicolor* and root diseases (root rot and wilt) were common in plantations located in high rainfall areas.

Severe wilt (vascular wilt caused by *Fusarium solani*), basal stem rot and root rot caused by *Ganoderma lucidum* were noticed in 1-2-year-old *Acacia mangium* Willd. plantations in the State. *Eucalyptus grandis* plantations at high elevated areas registered very severe stem infection caused by *Cryphonectria cubensis.*

In forest plantations, 0.90% of the total disease specimens from all the forest ecosystems were found infected with fungi. In other words, about 3.91% of the total plant host species specimens collected from different forest ecosystems, harbors pathogenic fungi in the plantations. Forest plantations registered very high fungal species richness values which are close to those recorded for the moist-deciduous forests. Among the eight

forest ecosystems studied, forest plantations registered the highest fungal species diversity indices (Table 15); about 106 fungal pathogens were found causing various diseases in this ecosystem. Among the host plants, exotic species were found most vulnerable to these fungal pathogens at their different growth phases.

Table 15: Species richness and diversity indices of plant pathogenic fungi in the forest plantations

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
19	5.665241	17.697342	0.0228204041	4.102671

Table 16: Fungal species abundance in the forest plantations

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Guignardia* sp.	21	6.23
2	*Colletotrichum gloeosporioides*	19	5.63
3	*Glomerella cingulata*	18	5.34
4	*Phomopsis* sp.	17	5.04
5	*Coniella fragariae*	14	4.15
6	*Corticium salmonicolor*	12	3.56
7	*Alternaria* sp.	12	3.56
8	*Pestalotiopsis maculans*	12	3.56
9	*Cylindrocladium quinqueseptatum*	10	2.96
10	*Curvularia* sp.	10	2.96
11	*Lasiodiplodia theobromae*	10	2.96
12	*Guignardia citricarpa*.	10	2.96

Among 106 fungal pathogens recorded from this ecosystem, common fungal pathogens like *Guignardia* sp., *Colletotrichum gloeosporioides*, *Glomerella cingulata*, *Phomopsis* sp., etc. showed abundance. Of the nine species of *Cylindrocaldium* recorded, *C. quinqueseptatum* was found the most virulent as well as predominant fungal pathogen in this ecosystem. Similarly, among various species of *Coniella*, recorded from the forest plantations, *C. fragariae* was the most abundant species (Table16). *Corticium salmonicolor*, the most dreaded canker pathogen was also found abundant in forest plantations affecting both indigenous as well as exotic plantation species.

Forest nurseries

Disease survey carried out in forest nurseries (10 nurseries) located in 6 Forest Ranges in the State, revealed fungal infection in 154 plant species. A total of 582 fungal isolates belonging to 45 fungal genera were found associated with the seedling diseases in nurseries. *Coniella, Cylindrocladium, Colletotrichum, Cercospora, Corynespora, Fusarium, Glomerella, Phoma, Phomopsis, Rhizoctonia, Sclerotium,* etc. are the important nursery pathogens. Conventional forest nurseries support a large number of fungal pathogens. In the forest nurseries, introduction of root trainer technology has had a tremendous impact on the seedling production system including nursery diseases caused by several fungal pathogens. As soil less or soil-free growing media are used in the root trainers for raising seedlings, most of the soil-borne pathogens were totally excluded from the nursery production system. However, new foliage pathogens like *Phoma glomerata* and *P. eupyrena* have attained new status in the nurseries causing severe damage of seedlings. Species richness indices as well as species diversity indices were found higher than the wet evergreen, shola forests and dry deciduous forests (Table 17). Among the 45 fungal pathogens encountered in this forest ecosystem, *Rhizoctonia solani* and *Sclerotium rolfsii* exhibited their abundance (Table 18).

Table 17: Species richness and diversity indices of plant pathogenic fungi in the forest nurseries

No. of study plots	Menhinick's index (R2)	Margalef's index (R1)	Simpson's index	Shannon index (H')
10	3.946761	9.039484	0.0578413834	3.200247

Table 18: Fungal species abundance in the forest nurseries

Sl. No.	Abundant fungal species	No. of host plants affected	% to total
1	*Rhizoctonia solani*	16	12.30
2	*Colletotrichum gloeosporioides*	16	12.30
3	*Sclerotium rolfsii*	15	11.53
4	*Phomopsis* sp.	11	8.46
5	*Glomerella cingulata*	9	6.92
6	*Guignardia* sp.	8	6.15

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LEGEND FOR PHOTOGRAPHIC PLATES

Plate No.1. 1: *Myrothecium roridum* colony on PDAmedium; 2: *Myrothecium gramineum* colony; 3:*Myrothecium masonii* colony; 4: *Fusarium culmorum* colony on PDA medium; 5:*Fusarium decemcellulare*; 6: *Coniella fragariae*; 7: *Fusarium oxysporum*; 8: *F. culmorum;* 9: *F. solani*; 10: *F. semitectum*; 11: *F. solani*; 12: *F. moniliforme* colony

Plate No.2. 1: *Adhathoda vasica – Rhizoctonia solani* leaf spots; 2: *Pterocarpus marsupium – R. solani* leaf blight; 3: *Albizia odoratissima – Camptomeris* leaf spots; 4: *Pongamia pinnata - Sclerotium rolfsii* leaf blight; 5: *Pterocarpus santalinus – Phomopsis* leaf blight; 6: *Kaempferia galanga Rhizoctonia solani* leaf spots; 7: *Pterocarpus marsupium – Sclerotium rolfsii* leaf blight; 8: *Acacia mangium: Colletotrichum gloeosporioides* leaf spot.

Plate No. 3. 1: *Albizia lebbeck - Rhizoctonia solani* web blight; 2: *Pterocarpus marsupium – Sclerotium rolfsii* leaf blight; 3: *Dalbergia sissoides – Rhizoctonia solani* damping-off; 4: *Pterocarpus marsupium – Sclerotium rolfsii* leaf blight; 5: *Tectona grandis- Phoma* leaf bight; 6: *Cassia fistula – Phomopsis* leaf spot; 7: *Acacia mangium – Cylindrocladium quinqueseptatum* leaf blotch; *Tectona grandis – Phoma* leaf blight.

Plate No. 4. 1: *Albizia odoratissima – Camptomeris* leaf spot; *Xylia xylocarpa – Pestalotiopsis* leaf spot; 2: *Azadirachta indica – Cylindrocladium scoparium* leaf spot; 4; *Pterocarpus santalinus – Rhizoctonia solani: Pongamia pinnata – Colletotrchum capsici* leaf spot; 6: *Syzygium cumini – Guignardia* leaf spot; 7: *Cinnamomum zeylanicum – Phomopsis* leaf spot; 8: *Grevillea robusta – Glomerella cingulata* – foliage blight; 9: *Cinnamomum malabatrum – Colletotrichum* leaf blight.

Plate No. 5. 1: *Eucalyptus tereticornis – Coniella* leaf blight; 2: *Bombax insigne – Myrothecium roridum* leaf spots; 3: *Tectona grandis – Phomopsis* target leaf spot; 4: *Camelia sinensis – Exobasidium vexans* blister blight; 5: *Bombax ceiba – Myrothecium roridum* leaf spots; 6:*Acacia mangium – Oidium*, powdery mildew; 7:*Pinus* sp. – *Colletotrichum* needle blight; 8;*Eucalyptus grandis- Cylindrocladium* leaf spots; 9:*Eucalyptus tereticornis – Coniella* leaf blotch.

Plate No. 6. 1: *Helicteres isora –Mycovellosiella* target spot; 2: *Pterocarpus marsupium – Phomopsis* leaf blight; 3: *Ochlandra travancorica – Fusarim semitectum* leaf blight; *Mitragyna parvifolia – Phomopsis* leaf spots; 5: *Cycas circinalis – Glomerella* leaf spots; *Dillenia pentagyna –Colletotrichum* leaf blotch; *Terminalia paniculata- Phomopsis* target sopots; *Ficus hispida – Mycovellosiella* target spot; *Macaranga peltata – Coniella fragariae* spots.

Plate No. 7. 1: *Polyalthia coffeoides – Colletotrichum* leaf spots; 2: *Ochlandra travancorica – Balansia* witches' broom; 3:*Tetrameles nudiflora – Phomopsis* leaf spot; 4: *Eucalyptus tereticornis – Cylindrocladium* leaf spots; 5: *Tectona grandis – Phomopsis* leaf spot; 6: *Eucalyptus tereticornis- Cryptosporiopsis* leaf spots; 7: *Tectona grandis – Scleotium rolfsii* leaf blight; 8; *Eucalyptus camaldulensis- Cryptosporiopsis* leaf spots; *E. tereticornis- Aulographina* leaf spot.

Plate No. 8. 1:*Terminalia paniculata – Cryphonectria gyrosa* stem canker; 2: *Eucalyptus grandis – Cryphonectria cubensis* canker; 3: *Acacia mangium – Botryosphaeria* canker; 4: *Acacia mangium- Ganoderma lucidum*- basal stem rot; 5: *Acacia mangium* – pink disease caused by *Corticium salmonicolor*; 6: *Eucalyptus tereticornis- Cylindrocladium* twig blight; 7: *Tectona grandis – Phoma* leaf blight; 8: *Azadirachta indica – Fusarium* twig blight; 9: *Eucalyptus tereticornis* – pink disease caused by *Corticium salmoniclor.*

Plate No. 9: *Acacia auriculiformis*- die-back caused by *Botryosphaeria* ; 2: *Acacia mangium*- vascular wilt caused by *Fusarium solani*; 3: Cupresses sp. – Colletotrichum foliage blight; 3: Teak – basal stem and root rot caused by *Lasiodiplodia theobromae*; 5;: *Eucalyptus tereticornis* – foliage blight caused by

Phaeophleospora eucalypti; Acacia auriculiformis- canker caused by Valsa sp.; 7,8: *Eucalyptus tereticornis* – Cryptosporiopsis leaf spot and Mycosphaerella leaf spots.

Plate 10: 1. *Dysoxylum malabaricum* - *Colletotrichum* leaf spots;2: *Dysoxylum malabaricum* - *Phoma* leaf spot; : 3: *Gmelina arborea* - *Pseudocercospra* leaf spot; 4: *Dalbergia latifolia* - *Phomopsis* leaf spots: 5: *Pterocarpus marsupium- Phomopsis* leaf spots; 6: *Gluta travancorica Pestalotiopsis* -leaf blight 7: *Syzygium cumini – Guignardia* leaf spot; 8: *Allophyllus cobbe – Phomopsis* leaf spot; 9: *Meliosma pinnata – Colletotrichum gloeosporioides* leaf spot.

Plate No. 11. 1: *Olea dioica – Cylindrocladium* leaf blight; 2: *Erythrina stricta – Colletotrichum* leaf spot; 3: *Actinodaphne malabarica – Colletotrichm* sp. associated with leaf galls; *Bischofia javanica – Glomerella cingulata* leaf spots; *Cinnamomum malabatrum- Colletotrichum gloeosporioides* target spot; 6,7: *Cordia gharaf – Aecidium* leaf rust; 8: *Maesa indica – Myrothecium roridum* leaf spots; ; 9: *Syzygium cumini – Guignardia* lead blotch;10: *Olea dioica – Phomopsis* target spots; 11: *Litsea* sp. – *Colletotrichum* leaf spots.

Plate No. 12. 1: *Bischofia javanica* - *Pestalotiopsis uvicola* leaf spots; 2, 3: *Meliosma simplicifolia – Aecidium* leaf rust; 4, 5: *Clerodendrum viscosum – Fusarim* sp. leaf blotch, 6: *Cinnamomum malabatrum – Pestalotiopsis maculans* leaf blotch; 7: *Aporusa lindleyana – Cylindrocladium quinqueseptatum* leaf blotch; 8: *Mitragyna parvifolia – Phomopsis* leaf blotch; 9: *Symplocos* sp. – *Phyllachora* tar spot.

Plate No. 13. 1,2: *Neolamarckia cadamba – Phomopsis* leaf spots; 2: *Lagerstroemia* sp. *Phyllachora* tar spots; 4-6: *Ixora notoniana – Pestalotiopsis* sp., *Alternaria* leaf spots; 7: *Strychnos potatorum – Colletotrichum* leaf spots; 8; *Litsea* sp. *Phomopsis* leaf spots.

Plate No. 14. 1 : *Garcinia gummi-gutta – Coniella minima* leaf blotch; 2: *Pterocarpus marsupium- Pestalotiopsis* leaf blotch; 3: *Haldina cordifolia – Phoma* leaf spots; 4: *Strychnos nux-vomica – Colletotrichum* leaf spots; 5: *Tetrameles nudiflora – Coniella* leaf spots; 6: *Dysoxylum malabaricum – Sclerotim rolfsii* leaf spots; 7: *Wrightia tinctoria – Giuignardia* leaf spots; 8: *Calamus thwaitesii – Sphaerodothis* sp. leaf spot; 9: *Oclandra travancoricus – Colletotrichum, Coniella leaf* spots.

Plate No. 15. 1: *Terminalia paniculata – Phomopsis* leaf spots; 2: *Dioscorea pentaphylla – Phomopsis* leaf spots; 3: *Ficus hispida – Phomopsis* sp.; *Aporusa lindleyana – Cylindrocladium* leaf blotch; 5: *Polyalthia fragrans – Glomerella* leaf blotch; 6 : *Aporusa lindleyana – Cylindrocladium* leaf blotch; 7: *Mitragyna parvifolia – Colletotrichum* sht hole; 8: *Mallotus Philippensis – Phomopsis* leaf spot; 9: *Diospyros sp.- Phomopsis* leaf spots.

Plate No. 16. 1: *Cinnamomum verum- Phomopsis* leaf spots; 2: *Xanthophyllum arnottianum – Colletotrichum* leaf spots; 3: *Cassia fistula – Septoria* leaf spots; 4: *Bridelia scandens – Colletotrichum* leaf spots; 5: *Glycosmis pentaphylla – Glomerella cingulata* leaf spots; 6: *Terminalia paniculata – Phomopsis* shot-hole; 7: *Bombax ceiba – Myrothecium roridum* leaf spots; 8: *Bombax insigne – Myrothecium* l;eaf spot; 9: *Haldinia cordifolia – Phomopsis* leaf spots.

Plate No. 17. 1: *Syzygium palghatense – Phoma* foliage and flower bud blight; 2: Unidentified host plant- *Phomopsis* leaf spot; 3: *Gmelina arborea – Coniella* leaf spot; 4,5: *Pongamia pinnata – Urohendersonia* leaf spots; *Hopea parviflora – Phomopsis* leaf spot; 7: *Cinnamomum malabatrum – Beltrania rhombica* leaf spots; 8: *Madhuka longifolia – Phomopsis* leaf blotch; 9: *Helicteres isora – Mycovellosiella* leaf spots; 10 *Dalbergia latifolia – Phyllachora* leaf spots.

Plate No. 18. 1: *Neolamarckia cadamba* - *Phomopsis* leaf spots; 2: *Eucalyptus pellita – Coniella* leaf spot; 3; *Vateria indica – Pestalotiopsis maculans* leaf spots; 4: *Acacia mangium – Glomeralla cingulata* leaf spots; 5: *Garcinia gummigutta- Coniella minima* leaf spots; 6: *Sapindus trifoliate – Pestalotiopsis* leaf blotch; 7: *Bauhinia variegata – Colletotrichum* leaf blotch; Unidentified host plant- *Puccinia* sp.; *Strobilanthes luridus – Aecidium* leaf rust; 10: *Flacourtia montana – Colletotrichum* leaf blotch; 11: Unidentified host – *Glomerella cingulata* leaf spots; *Dalbergia latifolia – Uredo sissoo* leaf rust.

Plate No.19. 1: *Canthium – Uromyces* leaf rust; 2: *Mitragyna parvifolia – Colletotrichum* leaf spots; 3: *Pongamia pinnata – Urohendersonia* leaf spots; 4: *Gluta travancoricus- Pestalotiopsis* leaf blotch; 5: Unidentified hosts- *Colletotrichum* leaf spots; 6: *Acacia auriculiformis – Meliola* bl;ack ildew; 7: *Albizia odoratissima Uromyces* leaf rust; 8:*Tectona grandis – Pseudoepicoccum* leaf spots; 8: *Eucalyptu pellita – Coniella* leaf spots.

Plate No.20. 1: Aeciospores (*Aecidium* rust infection in *Meliosma simplicifolia*); 2: Teleutospores of *Albizia* rust (*Uromyces*); 3: *Ravenelia emblicae* - section through teleutosori,; 4: Teleutospores; 5: Aecia (*Aecidium* sp.) infection in *M. simplicifolia*; 6: Section through Teleutosori (*Uromyces – A. lebbeck*); 7: Aecial cups in *M. simplicifolia*; 8: Aecial column and aeciospores (Aecidium sp. in *M. simplisifolia*).

Plate No. 21. 1,2: *Uredo terminaliae* rust pustules; 3: *Roestalia* pustules in *Meliosma pinnata* (Roxb.) Maxim. ssp.*barbulata*; 4: *Crossospora premnaetomentosae* leaf rust in *Premna tomentosa*; 5: *Uredo* sp. rust pustules on *Plumeria rubra* leaf.; 6: *Zaghouania olea* rust in *Olea dioica*; 7,8: *Olivia tectonae* rust pustules in *Tectona grandis*.

Plate No. 22. 1: *Aecidium* aecial cups in *Diospyros* sp.; 2: *Uromyces* teleutosori on *Canthium* sp., 3: *Cryphonectria cubensis* spore (pycnidiospores) tendril on *Eucalyptus grandis* stem; 4: Leaf rust of *Premna tomentosa*; 5: *Septoria* spore masses on *Cassia fistula* leaf; 6: *Aulographina* infection on *Eucalyptus tereticornis* leaf; 7: *Myrothecium roridum* sporodochia; 8: *Coniella fragariae* pycnidia.

Plate No.23. 1: *Chaetospermum* stromata (6x); 2: *Myrothecium* sporodochia; 3: *Cercospora* spores on *Mitragyna parviflora*; 4: *Cylindrocladium quinqueseptatum* conidia; 5: *Beltrania* sp. conidia and conidiophores ; 6: *Mycosphaerella*- asci and ascospores; 7: *Pullospora* conidia; 8: *Colletotrichum capsici* conidia and seta.

Appendix III: Pathogen Index

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Appendix I: Details on sites selected for the fungal biodiversity study in the Western Ghats

1.Northern Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
1	Kannur	1	Kannavam	N	Kadalkandam Nursery
				N	Cheruvanchery Nursery
				SEF	Mundayadu Medicinal Garden
				SEF	Kadalkandam
				SEF	Peruvam
				MDF	Kannoth
				EF	Nedumpoyil
		2	Kottiyur	EF	Kottiyur
		3	Thaliparamba	MDF	Thaliparamba
		4	Kanhangad	EF	Manjuchola
		5	Kasaragod	SEF	Parappa
2	Calicut	6	Peruvannamoozhy	P	Peruvannamuzhy
		7	Kuttiyadi	MDF	Kuttiyadi
		8	Thamarassery	EF	Kanalad
				SEF	Thamarassery Churam
				MDF	Thenhippalam
3	Wayanad North	9	Begur	SEF	Thrissillery, Muthumary
				SEF	Ambalamoola
				EF	Brahmagiri
				EF	Kuruva Island
		10	Periya	EF	Chandanathodu
				EF	Periya
				SEF	Alat
				SEF	Ambalakkandy
		11	Mananthavady	MDF	Mananthavady
				MDF	Varayal
4	Wayanad South	12	Kalpetta	P / MDF	Thariode
				SEF	Kalpetta
				SEF	Puthurvayal
				MDF	Manikunnumala
		13	Meppady	MDF	Kaappankolli
				SF	Meppady chola, Chembra peek
				MDF	Pookodu
		14	Chethalath	MDF	Chethalath
				MDF	Kuppady
5	Wyanad WLD	15	Tholpetty	MDF	Tholpetty
				MDF	Kudhirakkode
				MDF	Appapara
				MDF	Kattikulam
				SEF	Thirunelli
				SEF	Moolappara
		16	Kurichiyath	MDF	Goloor
				MDF	Vandikadavu
				MDF	Kurichiyad
				SEF	Palammoola
		17	Muthanga	MDF	Muthanga
				SEF	Noolpuzha
		18	Sulthan Bathery	MDF	Rampur
				P	Muthanga North
		19	Aralam WLS	EF	Aralam
				EF	Meenmutty

2. Olavakkode Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
6	Nilambur North	20	Nilambur	MDF	KFRI Sub Center
				N	Valluvassery Central Nursery
				MDF	Valluvassery
		21	Edavanna	MDF	Edavanna
		22	Vazhikadavu	MDF	Nellikuthu,Karappuram
				SEF	Nadukani Churam
				MDF	Anamari
7	Nilambur South	23	Kalikavu	MDF	Padukka, Palayankara
		24	Karulai	SEF	Injar
				SEF	Nedumkayam
				MDF	Churulipotti
				MDF	Kanjiramkodu
				SEF	Paattakarimbu
8	Mannarkad	25	Attappadi	WEF	Panthanthodu
				EF	Mukkali
		26	Agali	MDF	Manjachola
				MDF	Kollankadavu
				SEF	Paravalavu
				MDF	Kallamala
				MDF	Agali
		27	Mannarkad	EF	Mandampotty
				SEF	Churam
9	Palakkad	28	Olavakode	MDF	Mundoor
				MDF	Dhoni
		29	Walayar 240msl	MDF	Pudussery North (Palamarakoopu)
				MDF	Vattappara
		30	Ottapalam	P	Ottapalam
10	Nemmara	31	Nelliyampathy	EF	Pothumala
		32	Kollengode	P	Kollengode
		33	Alathur	P	Alathur
11	Silent Valley NP	34	Silent Valley NP	WEF	Sirendhri
12	Parambikulam WLD	35	Sungam	EF	Pandaravarii
				P	Sungam Teak plantationn.
		36	Parambikulam	MDF	Parambikulam
				SEF	Seethathodu
				MDF	Thunakadavu
				SEF	Pooppara
		37	Orukomban	P	Orukomban
		38	Karimala	P / MDF	Karimala

3. Central Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
13	Trichur	39	Vadakkanchery	P / MDF	Poongodu, Arissery
				P / MDF	Perinkunnam
				P	Kayampoovam
				P / MDF	Mayannur, Beetikunnu
				P / MDF	Methukku
				P / MDF	Poolakunnu
				MDF	Kuttimaruthu
		40	Pattikkad	SEF	Kuthiran, Van Vijnanakendram
		41	Machad	MDF	Machad
				SEF	Vazhani part of Machade
				MDF	Ungumchola
				MDF	Akamala
				MDF	Attoor, Asurankundu dam
14	Chalakudy	42	Pariyaram	MDF	Thumburmuzhi
				MDF	Karikadu
		43	Palappilly	MDF	Veluppadam
				N	Chettikulam Central Nursery
				MDF	Palappilly
		44	Vellikulangara	EF	Anapandam, Thachampally Reserve
				EF	Adivarathodu
				P / MDF	Punnakuzhi, way Rama Varma Teak Plantation
15	Vazhachal	45	Charpa	SEF	Charpa
				EF	Anappara
				P / SEF	Panjanamkuthu
		46	Vazhachal	SEF	Vazhachal
				EF	Sidhanpocket
				MDF	Irumpupalam
		47	Sholayar 900msl	EF	Malakkappara
				EF	Anakayam
				EF	KKN Plot Upper Sholayar
		48	Kollathirumedu	EF	Karadippara
				EF	Thavalakuzhippara
				SEF	Pathadipalam
		49	Athirappally	P / MDF	Vettilappara
				P / MDF	Athirappally
16	Malayattur	50	Kalady	MDF	Vazhakulam South
				P	Kalady
		51	Kodanadu	P / MDF	Kottappara
				P / MDF	Pezhad
				P / MDF	Plamudi
				P / MDF	Paniyeli
				MDF	Vembooram
		52	Thundathil	MDF	Malayattoor
				MDF	Pondanthodu
				MDF	Thundam
				SEF	Idamalayar
				SEF	Bhoothathankettu
		53	Kuttampuzha	P	Kuttampuzha
17	Peechi WLD	54	Peechi-Vazhani	MDF	Peechi KFRI Campus
				N	Orappanppara KFRI Nursery
				N	Marottichal KFD Nursery
				SEF	Kuthiran (Peechi side)
				MDF	KFRI Medicinal Garden
		55	Chimmony	SEF	Chimmony Dam site
				P	Chimmony

4. High Range Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
18	Kothamangalam	56	Thodupuzha	P	Vazhakulam
		57	Kothamangalam	P	Orukunnu
		58	Kaliyar	P	Kaliyar
		59	Mullaringad	P	Mullaringad
19	Munnar	60	Munnar	SEF	Mattupetti
				SF	Mannavan Shola
		61	Marayur	SF	Pambadum Shola
				P / SEF	Vattavada
				SEF	Chunduvaraii
				P / MDF	Anakallu
				P / MDF	Marayur Sandal Plot
		62	Devikulam	SEF	Upper Devikulam
				SF	Old Devikulam Shola
				SEF	Devikulam
				SEF	Devikulam Lake
				SF	Devimala Shola
		63	Adimali	P	Kaithachal
				P / MDF	Chenkulam
		64	Neryamangalam	MDF	Injathotti, Munippara
				MDF	Adichili
				MDF	Valara
20	Mankulam	65	Mankulam	SEF	Mankulam
		66	Anakulam	P	Anakulam
21	Kottayam	67	Erumeli	MDF	Plappilly, Erumeli
		68	Ayyappancoil	SEF	Kanjiyar (Pezhumkandam)
				P / MDF	Ayyappancoil
		69	Nagarampara	MDF	Nagarampara
				P	Nagarampara Eucaly. Plantation
		70	Kumili	MDF	Kumili
22	Idukki WLD	71	Idukki	MDF	Cheruthoni
		72	Thattekkad	SEF	Thattekkad
23	Eravikulam WLD	73	Eravikulam NP	SF	Eravikulam
		74	Chinnar	DDF	Chinnar
				DDF	Chinnar to Marayur
24	Thekkady WLD	75	Thekkady	SEF	Thekkady
		76	Vallakkadavu	SEF	Vallakadavu
				EF	Pachakkanam
				SEF	Gavi

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FD No: Forest Division Code; FR No: Forest Range Code; DDF: Dry Deciduous Forest; MDF: Moist Deciduous Forest; SEF: Semi Evergreen Forest; EF: Evergreen Forest; WEF: Wet Evergreen Forest; SF: Shola Forest; MS: Myristica Swamp Forest; P / MDF: Plantations within Moist Deciduous Forest; P / SEF: Plantations within Semi Evergreen Forest; P: Plantations; N: Nurseries

5. Southern Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
25	Ranni	77	Ranni	MDF	Chittar
				SEF	Kattachira
				SEF	Neelipilavu
				SEF	Angamoozhy
				SEF	Ottuppara
		78	Goodrickal	EF	Gurunathanmannu
				MDF	Rajampara
				SEF	Nilakkal
				EF	Chinnakayam
				EF	Chalakayam
				EF	Manipuzha
				SEF	Plachery
				SEF	Pamba
				SEF	Kundanpuzha
		79	Vadasserikkara	SEF	Chelikuzhi
				SEF	Nellimala, Kanamala
				MDF	Elavumkallu
26	Konni	80	Konni	N	Konni Nursery
				N	North Kumaramperur
				P / MDF	Ilamullumplakal
		81	Naduvathumuzhi	P / MDF	Naduvathumuzhi
				P / MDF	Kokkathodu
		82	Mannarappara	P	Mannarappara
27	Achenkovil	83	Achenkovil	P / MDF	Achenkovil
		84	Kallar	P / MDF	Kallar
		85	Kanayar	P / MDF	Kanayar
28	Punalur	86	Anchal	P / MDF	Pathupara
				P / MDF	Kelankavu
				SEF	Urakkathumpara
				MDF	Onthupacha
				SEF	Sanjeevani Vanam
				P / MDF	Maruthimoodu
		87	Pathanapuram	P / MDF	Punnala
				P / MDF	Kadakam
				MDF	Kaithakettu
29	Thenmala	88	Arienkavu	P / MDF	Arienkavu
		89	Thenmala	P / MDF	Kattileppara
				SEF	Palaruvi
				P / MDF	Choodal
30	Trivandrum	90	Kulathupuzha	N	Kandamchira KFD Nursery
				MS	Arippa
				MDF	Peringamala, Chittoor
				P / MDF	Kulathupuzha
				N	Kandamchira
				P / MDF	Kulathupuzha KFRI Plot
				P / MDF	Choolady
				EF	Ammayambalam
		91	Palode	SEF	Braemore
				P / MDF	Palode
		92	Paruthippally	SEF	Ponmudi
31	Shendurney WLD	93	Shendurney	P / MDF	Sangily, Nadathara
		94	Peppara	MDF	Peppara
32	Trivandrum WLD	95	Neyyar	MDF	Neyyar dam site
33	Agasthyavanam	96	Agasthyavanam	SEF	Kottoor Reserve

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Appendix II: *Coniella* species identified from different host plants in the Western Ghats, Kerala

Herb No	Forest types	Forest Range	Forest locality	Host Botanical Name	Disease	Severity	Fungal Genera isolate 1
1473	P	Anchal	Kelankavu	Acacia auriculiformis A. Cunn.ex Benth.	Stem Infection	L	Coniella
4347	MDF	Marayur	Marayur	Anogeissus latifolia (Roxb.ex DC.) Wall.ex Guill. & Perr.	Leaf Spot	L	Coniella fragariae
2919	N	Peechi Vazhani	KFRI Silvi Nursery	Azadirachta indica A. Juss.	Leaf Spot	L	Coniella
4228	N	Palappilly	Central Nursery Chettikulam	Bombax ceiba L.	Leaf Spot	M	Coniella fragariae
3274	MDF	Muthanga	Muthanga	Butea monosperma (Lam.) Taub.	Leaf Blotch	L	Coniella fragariae
4229	N	Palappilly	Central Nursery Chettikulam	Canthium sp	Leaf Spot	M	Coniella fragariae
3345	EF	Periya	Chandanathodu	Careya arborea Roxb.	Leaf Target Spot	M	Coniella petrakii
145	MDF	Nilambur	KFRI Sc campus	Cleistanthus collinus Benth.	Leaf Spot	L	Coniella fragariae
3636	N	Peechi Vazhani	KFRI Silvi Nursery	Dalbergia latifolia Roxb.	Leaf Blotch	H	Coniella fragariae
3317	EF	Periya	Chandanathodu	Erythropalum scandens Blume	Leaf Angular Spot	L	Coniella fragariae
1485	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella
1486	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Tip Blight	L	Coniella
1548	P	Kulathupuzha	Kandamchira	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella
1489	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella fragariae
1546	P	Kulathupuzha	Kandamchira	Eucalyptus camaldulensis Dehnh.	Leaf Spot	M	Coniella fragariae
1685	P	Kodanadu	Kottapara	Eucalyptus camaldulensis Dehnh.	Leaf Blotch	L	Coniella fragariae
2582	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	H	Coniella fragariae
2583	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	H	Coniella fragariae

2584	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	M	Coniella fragariae
2586	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Blotch	M	Coniella fragariae
1684	P	Kodanadu	Kottapara	Eucalyptus camaldulensis Dehnh.	Leaf spot	L	Coniella fragariae
3000	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus citriodora Hook.	Leaf Spot	H	Coniella minima
3019	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Tip Blight	H	Coniella
1611	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella
1616	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella fragariae
1617	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella fragariae
1623	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	L	Coniella fragariae
3002	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella fragariae
3008	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella fragariae
3012	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella fragariae
3006	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf vein banding	H	Coniella fragariae + Coniella austalensis
3011	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Tip Blight	M	Coniella fragariae + Coniella minima
2998	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella minima
2999	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella petrakii
3003	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella petrakii
3017	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella petrakii
3020	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone K3	Leaf Spot	H	Coniella fragariae
2472	N	Thundathil	Bhoothathankettu HNL Nursery	Eucalyptus clone KFRI 16	Leaf Blotch	H	Coniella
3010	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone KFRI 25	Leaf Spot	H	Coniella fragariae
2476	N	Thundathil	Bhoothathankettu HNL Nursery	Eucalyptus clone KFRI 49	Leaf Blotch	L	Coniella
2580	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus clone P 14	Leaf Spot	H	Coniella fragariae
3340	P	Periya	Chandanathodu	Eucalyptus grandis Hill ex Maiden	Leaf Spot	L	Coniella fragariae
2819	P	Kalpetta	Thariode 11th mile	Eucalyptus grandis Hill ex Maiden	Leaf Blotch	M	Coniella fragariae

2570	N	Kulathupuzha	Central Nursery Decent Mook	Eucalyptus pellita Muell.	Leaf Spot	L	Coniella fragariae
2579	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Spot	L	Coniella fragariae
2590	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Blotch	L	Coniella fragariae
2592	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Blotch	L	Coniella fragariae
3001	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus pellita Muell.	Leaf Target spot	H	Coniella fragariae
4222	N	Palappilly	Central Nursery Chettikulam	Eucalyptus pellita Muell.	Leaf Spot	M	Coniella fragariae
4225	N	Palappilly	Central Nursery Chettikulam	Eucalyptus pellita Muell.	Leaf Spot	H	Coniella fragariae
1526	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith.	Leaf Spot	L	Coniella
139	P	Nilambur	KFRI Sc campus	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1474	P	Pathanapuram	Kadakam	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1514	P	Pathanapuram	Kaithakettu	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1519	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1523	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1525	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1597	P	Kulathupuzha	Kulathupuzha	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1670	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf Blotch	M	Coniella fragariae
1678	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf spot	L	Coniella fragariae
1733	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf spot	M	Coniella fragariae
1739	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf blotch	L	Coniella fragariae
2576	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Concentric Spot	M	Coniella fragariae
2591	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Leaf Spot	H	Coniella fragariae
2596	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Leaf Blotch	M	Coniella fragariae
2773	N	Nilambur	Central Nursery Valluvassery	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
3277	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae

3278	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
3886	SEF	Karulai	Pattakarimbu	Eucalyptus tereticornis Smith	Leaf Blotch	H	Coniella fragariae
3887	SEF	Karulai	Pattakarimbu	Eucalyptus tereticornis Smith	Leaf Blotch	H	Coniella fragariae
4234	N	Palappilly	Central Nursery Chettikulam	Eucalyptus tereticornis Smith	Leaf Spot	H	Coniella fragariae
1740	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf spot	L	Coniella fragariae
3280	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1669	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae + Coniella graneti
2995	P	Kulathupuzha	Arippa	Eucalyptus tereticornis Smith	Leaf Tar Spot	H	Coniella granatii
1618	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Blotch	L	Coniella fragariae
1619	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Spot	L	Coniella fragariae
1681	P	Kodanadu	Kottapara	Eucalyptus urophylla Blake	Leaf Blotch	L	Coniella fragariae
3005	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Blotch	H	Coniella fragariae
1321	MDF	Tholpetty	Tholpetty	Fern	Leaf Spot	L	Coniella fragariae
211	MDF	Nilambur	KFRI Sc campus	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	H	Coniella minima
1816	N	Peechi Vazhani	KFRI Silvi Nursery	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	L	Coniella minima
2981	SEF	Anchal	Sangeevani Vanam	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	H	Coniella minima
2376	EF	Vellikulangara	Anapandam	Gmelina arborea Roxb.	Leaf Spot / Target spot	M	Coniella
3677	MDF	Athirappally	Athirappally	Gmelina arborea Roxb.	Leaf Blotch	H	Coniella fragariae
3775	N	Palappilly	Central Nursery Chettikulam	Holarrhena pubescens (Buch.-Ham.) Wall.ex G. Don	Leaf Spot	H	Coniella
3674	MDF	Athirappally	Athirappally	Leea indica (Burm.f.) Merr.	Leaf Tip Blight	M	Coniella fragariae
2444	MDF	Thundathil	Panthanthodu	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Blotch	M	Coniella
4106	SEF	Goodrickal	Nilakkal	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Target Spot	H	Coniella
1759	MDF	Palappilly	Veluppadam	Macaranga peltata (Roxb.) Muell.-Arg	Leaf spot	L	Coniella australiensis
1566	P/SEF	Kulathupuzha	Arippa	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Spot	L	Coniella fragariae
4106	SEF	Goodricka	Nilakkal	Macaranga peltata	Leaf	H	Coniella fragariae

		l		(Roxb.) Muell.-Arg	Target Spot		
4342	MDF	Ayyappan kovil	Periyakanal-Anayirangal	Macaranga peltata (Roxb.) Muell.-Arg	Leaf Spot	H	Coniella fragariae
1484	P/MDF	Pathanapuram	Kadakam	Macaranga peltata (Roxb.) Muell.-Arg	Leaf Spot	H	Coniella fragariae
1688	P/MDF	Kodanadu	Kottapara	Mikania micrantha H.B.K.	Leaf spot	L	Coniella fragariae
3683	MDF	Athirappally	Athirappally	Ochlandra travancorica Benth. ex Gamble	Leaf Spot	H	Coniella fragariae
4120	EF	Goodrickal	Chinnakayam	Ochlandra travancorica Benth. ex Gamble	Leaf Target Spot	H	Coniella fragariae
3675	MDF	Athirappally	Athirappally	Persea macrantha (Nees) Kosterm.	Leaf Spot	L	Coniella fragariae
2975	SEF	Anchal	Sangeevani Vanam	Persea macrantha (Nees) Kosterm.	Leaf Gall	L	Coniella frageriae
3283	MDF	Muthanga	Muthanga	Pongamia glabra Vent.	Leaf Tip Blight	L	Coniella
4226	N	Palappilly	Central Nursery Chettikulam	Strychnos nux-vomica L.	Sooty Mould	M	Coniella fragariae
2977	SEF	Anchal	Sangeevani Vanam	Syzygium caryophyllatum (L.) Alston	Leaf Spot	M	Coniella petrakii
3357	EF	Periya	Chandanathodu	Syzygium mundagam (Bourd.) Chitra	Leaf Spot	L	Coniella fragariae
147	MDF	Nilambur	KFRI Sc campus	Tabernaemontana heyneana Wall.	Leaf Spot	L	Coniella fragariae
2697	MDF	Agasthyavanam	Kotoor	Terminalia chebula Retz.	Leaf Spot	M	Coniella fragariae
146	MDF	Nilambur	KFRI Sc campus	Terminalia paniculata Roth	Leaf Spot	L	Coniella fragariae
144	MDF	Nilambur	KFRI Sc campus	Terminalia paniculata Roth	Leaf Spot	L	Coniella fragariae
3891	MDF	Kodanadu	Vembooram	Tetramelus nudiflora R.Br.	Leaf Spot	M	Coniella
1789	SEF	Chimmony	Chimmony Dam	Unidentified host plant	Leaf spot	L	Coniella
3292	EF	Periya	Chandanathodu	Unidentified host plant	Leaf Angular Spot	L	Coniella minima
3609	N	Nilambur	Central Nursery Valluvassery	Vateria indica L.	Leaf Blotch	L	Coniella castaneicola

Appendix I: Details on sites selected for the fungal biodiversity study in the Western Ghats

1.Northern Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
1	Kannur	1	Kannavam	N	Kadalkandam Nursery
				N	Cheruvanchery Nursery
				SEF	Mundayadu Medicinal Garden
				SEF	Kadalkandam
				SEF	Peruvam
				MDF	Kannoth
				EF	Nedumpoyil
		2	Kottiyur	EF	Kottiyur
		3	Thaliparamba	MDF	Thaliparamba
		4	Kanhangad	EF	Manjuchola
		5	Kasaragod	SEF	Parappa
2	Calicut	6	Peruvannamoozhy	P	Peruvannamuzhy
		7	Kuttiyadi	MDF	Kuttiyadi
		8	Thamarassery	EF	Kanalad
				SEF	Thamarassery Churam
				MDF	Thenhippalam
3	Wayanad North	9	Begur	SEF	Thrissillery, Muthumary
				SEF	Ambalamoola
				EF	Brahmagiri
				EF	Kuruva Island
		10	Periya	EF	Chandanathodu
				EF	Periya
				SEF	Alat
				SEF	Ambalakkandy
		11	Mananthavady	MDF	Mananthavady
				MDF	Varayal
4	Wayanad South	12	Kalpetta	P / MDF	Thariode
				SEF	Kalpetta
				SEF	Puthurvayal
				MDF	Manikunnumala
		13	Meppady	MDF	Kaappankolli
				SF	Meppady chola, Chembra peek
				MDF	Pookodu
		14	Chethalath	MDF	Chethalath
				MDF	Kuppady
5	Wyanad WLD	15	Tholpetty	MDF	Tholpetty
				MDF	Kudhirakkode
				MDF	Appapara
				MDF	Kattikulam
				SEF	Thirunelli
				SEF	Moolappara
		16	Kurichiyath	MDF	Goloor
				MDF	Vandikadavu
				MDF	Kurichiyad
				SEF	Palammoola
		17	Muthanga	MDF	Muthanga
				SEF	Noolpuzha
		18	Sulthan Bathery	MDF	Rampur
				P	Muthanga North
		19	Aralam WLS	EF	Aralam
				EF	Meenmutty

2. Olavakkode Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
6	Nilambur North	20	Nilambur	MDF	KFRI Sub Center
				N	Valluvassery Central Nursery
				MDF	Valluvassery
		21	Edavanna	MDF	Edavanna
		22	Vazhikadavu	MDF	Nellikuthu,Karappuram
				SEF	Nadukani Churam
				MDF	Anamari
7	Nilambur South	23	Kalikavu	MDF	Padukka, Palayankara
		24	Karulai	SEF	Injar
				SEF	Nedumkayam
				MDF	Churulipotti
				MDF	Kanjiramkodu
				SEF	Paattakarimbu
8	Mannarkad	25	Attappadi	WEF	Panthanthodu
				EF	Mukkali
		26	Agali	MDF	Manjachola
				MDF	Kollankadavu
				SEF	Paravalavu
				MDF	Kallamala
				MDF	Agali
		27	Mannarkad	EF	Mandampotty
				SEF	Churam
9	Palakkad	28	Olavakode	MDF	Mundoor
				MDF	Dhoni
		29	Walayar 240msl	MDF	Pudussery North (Palamarakoopu)
				MDF	Vattappara
		30	Ottapalam	P	Ottapalam
10	Nemmara	31	Nelliyampathy	EF	Pothumala
		32	Kollengode	P	Kollengode
		33	Alathur	P	Alathur
11	Silent Valley NP	34	Silent Valley NP	WEF	Sirendhri
12	Parambikulam WLD	35	Sungam	EF	Pandaravarii
				P	Sungam Teak plantationn.
		36	Parambikulam	MDF	Parambikulam
				SEF	Seethathodu
				MDF	Thunakadavu
				SEF	Pooppara
		37	Orukomban	P	Orukomban
		38	Karimala	P / MDF	Karimala

3. Central Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
13	Trichur	39	Vadakkanchery	P / MDF	Poongodu, Arissery
				P / MDF	Perinkunnam
				P	Kayampoovam
				P / MDF	Mayannur, Beetikunnu
				P / MDF	Methukku
				P / MDF	Poolakunnu
				MDF	Kuttimaruthu
		40	Pattikkad	SEF	Kuthiran, Van Vijnanakendram
		41	Machad	MDF	Machad
				SEF	Vazhani part of Machade
				MDF	Ungumchola
				MDF	Akamala
				MDF	Attoor, Asurankundu dam
14	Chalakudy	42	Pariyaram	MDF	Thumburmuzhi
				MDF	Karikadu
		43	Palappilly	MDF	Veluppadam
				N	Chettikulam Central Nursery
				MDF	Palappilly
		44	Vellikulangara	EF	Anapandam, Thachampally Reserve
				EF	Adivarathodu
				P / MDF	Punnakuzhi, way Rama Varma Teak Plantation
15	Vazhachal	45	Charpa	SEF	Charpa
				EF	Anappara
				P / SEF	Panjanamkuthu
		46	Vazhachal	SEF	Vazhachal
				EF	Sidhanpocket
				MDF	Irumpupalam
		47	Sholayar 900msl	EF	Malakkappara
				EF	Anakayam
				EF	KKN Plot Upper Sholayar
		48	Kollathirumedu	EF	Karadippara
				EF	Thavalakuzhippara
				SEF	Pathadipalam
		49	Athirappally	P / MDF	Vettilappara
				P / MDF	Athirappally
16	Malayattur	50	Kalady	MDF	Vazhakulam South
				P	Kalady
		51	Kodanadu	P / MDF	Kottappara
				P / MDF	Pezhad
				P / MDF	Plamudi
				P / MDF	Paniyeli
				MDF	Vembooram
		52	Thundathil	MDF	Malayattoor
				MDF	Pondanthodu
				MDF	Thundam
				SEF	Idamalayar
				SEF	Bhoothathankettu
		53	Kuttampuzha	P	Kuttampuzha
17	Peechi WLD	54	Peechi-Vazhani	MDF	Peechi KFRI Campus
				N	Orappanppara KFRI Nursery
				N	Marottichal KFD Nursery
				SEF	Kuthiran (Peechi side)
				MDF	KFRI Medicinal Garden
		55	Chimmony	SEF	Chimmony Dam site
				P	Chimmony

4. High Range Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
18	Kothamangalam	56	Thodupuzha	P	Vazhakulam
		57	Kothamangalam	P	Orukunnu
		58	Kaliyar	P	Kaliyar
		59	Mullaringad	P	Mullaringad
19	Munnar	60	Munnar	SEF	Mattupetti
				SF	Mannavan Shola
		61	Marayur	SF	Pambadum Shola
				P / SEF	Vattavada
				SEF	Chunduvaraii
				P / MDF	Anakallu
				P / MDF	Marayur Sandal Plot
		62	Devikulam	SEF	Upper Devikulam
				SF	Old Devikulam Shola
				SEF	Devikulam
				SEF	Devikulam Lake
				SF	Devimala Shola
		63	Adimali	P	Kaithachal
				P / MDF	Chenkulam
		64	Neryamangalam	MDF	Injathotti, Munippara
				MDF	Adichili
				MDF	Valara
20	Mankulam	65	Mankulam	SEF	Mankulam
		66	Anakulam	P	Anakulam
21	Kottayam	67	Erumeli	MDF	Plappilly, Erumeli
		68	Ayyappancoil	SEF	Kanjiyar (Pezhumkandam)
				P / MDF	Ayyappancoil
		69	Nagarampara	MDF	Nagarampara
				P	Nagarampara Eucaly. Plantation
		70	Kumili	MDF	Kumili
22	Idukki WLD	71	Idukki	MDF	Cheruthoni
		72	Thattekkad	SEF	Thattekkad
23	Eravikulam WLD	73	Eravikulam NP	SF	Eravikulam
		74	Chinnar	DDF	Chinnar
				DDF	Chinnar to Marayur
24	Thekkady WLD	75	Thekkady	SEF	Thekkady
		76	Vallakkadavu	SEF	Vallakadavu
				EF	Pachakkanam
				SEF	Gavi

*****

FD No: Forest Division Code; FR No: Forest Range Code; DDF: Dry Deciduous Forest; MDF: Moist Deciduous Forest; SEF: Semi Evergreen Forest; EF: Evergreen Forest; WEF: Wet Evergreen Forest; SF: Shola Forest; MS: Myristica Swamp Forest; P / MDF: Plantations within Moist Deciduous Forest; P / SEF: Plantations within Semi Evergreen Forest; P: Plantations; N: Nurseries

5. Southern Circle and Protected Areas

FD No	Forest Divisions	FR No	Forest Ranges	Forest Types	Locality
25	Ranni	77	Ranni	MDF	Chittar
				SEF	Kattachira
				SEF	Neelipilavu
				SEF	Angamoozhy
				SEF	Ottuppara
		78	Goodrickal	EF	Gurunathanmannu
				MDF	Rajampara
				SEF	Nilakkal
				EF	Chinnakayam
				EF	Chalakayam
				EF	Manipuzha
				SEF	Plachery
				SEF	Pamba
				SEF	Kundanpuzha
		79	Vadasserikkara	SEF	Chelikuzhi
				SEF	Nellimala, Kanamala
				MDF	Elavumkallu
26	Konni	80	Konni	N	Konni Nursery
				N	North Kumaramperur
				P / MDF	Ilamullumplakal
		81	Naduvathumuzhi	P / MDF	Naduvathumuzhi
				P / MDF	Kokkathodu
		82	Mannarappara	P	Mannarappara
27	Achenkovil	83	Achenkovil	P / MDF	Achenkovil
		84	Kallar	P / MDF	Kallar
		85	Kanayar	P / MDF	Kanayar
28	Punalur	86	Anchal	P / MDF	Pathupara
				P / MDF	Kelankavu
				SEF	Urakkathumpara
				MDF	Onthupacha
				SEF	Sanjeevani Vanam
				P / MDF	Maruthimoodu
		87	Pathanapuram	P / MDF	Punnala
				P / MDF	Kadakam
				MDF	Kaithakettu
29	Thenmala	88	Arienkavu	P / MDF	Arienkavu
		89	Thenmala	P / MDF	Kattileppara
				SEF	Palaruvi
				P / MDF	Choodal
30	Trivandrum	90	Kulathupuzha	N	Kandamchira KFD Nursery
				MS	Arippa
				MDF	Peringamala, Chittoor
				P / MDF	Kulathupuzha
				N	Kandamchira
				P / MDF	Kulathupuzha KFRI Plot
				P / MDF	Choolady
				EF	Ammayambalam
		91	Palode	SEF	Braemore
				P / MDF	Palode
		92	Paruthippally	SEF	Ponmudi
31	Shendurney WLD	93	Shendurney	P / MDF	Sangily, Nadathara
		94	Peppara	MDF	Peppara
32	Trivandrum WLD	95	Neyyar	MDF	Neyyar dam site
33	Agasthyavanam	96	Agasthyavanam	SEF	Kottoor Reserve

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Appendix II: *Coniella* species identified from different host plants in the Western Ghats, Kerala

Herb No	Forest types	Forest Range	Forest locality	Host Botanical Name	Disease	Severity	Fungal Genera isolate 1
1473	P	Anchal	Kelankavu	Acacia auriculiformis A. Cunn.ex Benth.	Stem Infection	L	Coniella
4347	MDF	Marayur	Marayur	Anogeissus latifolia (Roxb.ex DC.) Wall.ex Guill. & Perr.	Leaf Spot	L	Coniella fragariae
2919	N	Peechi Vazhani	KFRI Silvi Nursery	Azadirachta indica A. Juss.	Leaf Spot	L	Coniella
4228	N	Palappilly	Central Nursery Chettikulam	Bombax ceiba L.	Leaf Spot	M	Coniella fragariae
3274	MDF	Muthanga	Muthanga	Butea monosperma (Lam.) Taub.	Leaf Blotch	L	Coniella fragariae
4229	N	Palappilly	Central Nursery Chettikulam	Canthium sp	Leaf Spot	M	Coniella fragariae
3345	EF	Periya	Chandanathodu	Careya arborea Roxb.	Leaf Target Spot	M	Coniella petrakii
145	MDF	Nilambur	KFRI Sc campus	Cleistanthus collinus Benth.	Leaf Spot	L	Coniella fragariae
3636	N	Peechi Vazhani	KFRI Silvi Nursery	Dalbergia latifolia Roxb.	Leaf Blotch	H	Coniella fragariae
3317	EF	Periya	Chandanathodu	Erythropalum scandens Blume	Leaf Angular Spot	L	Coniella fragariae
1485	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella
1486	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Tip Blight	L	Coniella
1548	P	Kulathupuzha	Kandamchira	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella
1489	P	Pathanapuram	Kadakam	Eucalyptus camaldulensis Dehnh.	Leaf Spot	L	Coniella fragariae
1546	P	Kulathupuzha	Kandamchira	Eucalyptus camaldulensis Dehnh.	Leaf Spot	M	Coniella fragariae
1685	P	Kodanadu	Kottapara	Eucalyptus camaldulensis Dehnh.	Leaf Blotch	L	Coniella fragariae
2582	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	H	Coniella fragariae
2583	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	H	Coniella fragariae

2584	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Spot	M	Coniella fragariae
2586	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus camaldulensis Dehnh.	Leaf Blotch	M	Coniella fragariae
1684	P	Kodanadu	Kottapara	Eucalyptus camaldulensis Dehnh.	Leaf spot	L	Coniella fragariae
3000	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus citriodora Hook.	Leaf Spot	H	Coniella minima
3019	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Tip Blight	H	Coniella
1611	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella
1616	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella fragariae
1617	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	L	Coniella fragariae
1623	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	L	Coniella fragariae
3002	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella fragariae
3008	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella fragariae
3012	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella fragariae
3006	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf vein banding	H	Coniella fragariae + Coniella austalensis
3011	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Tip Blight	M	Coniella fragariae + Coniella minima
2998	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella minima
2999	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Blotch	H	Coniella petrakii
3003	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella petrakii
3017	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone	Leaf Spot	H	Coniella petrakii
3020	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone K3	Leaf Spot	H	Coniella fragariae
2472	N	Thundathil	Bhoothathankettu HNL Nursery	Eucalyptus clone KFRI 16	Leaf Blotch	H	Coniella
3010	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus clone KFRI 25	Leaf Spot	H	Coniella fragariae
2476	N	Thundathil	Bhoothathankettu HNL Nursery	Eucalyptus clone KFRI 49	Leaf Blotch	L	Coniella
2580	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus clone P 14	Leaf Spot	H	Coniella fragariae
3340	P	Periya	Chandanathodu	Eucalyptus grandis Hill ex Maiden	Leaf Spot	L	Coniella fragariae
2819	P	Kalpetta	Thariode 11th mile	Eucalyptus grandis Hill ex Maiden	Leaf Blotch	M	Coniella fragariae

2570	N	Kulathupuzha	Central Nursery Decent Mook	Eucalyptus pellita Muell.	Leaf Spot	L	Coniella fragariae
2579	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Spot	L	Coniella fragariae
2590	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Blotch	L	Coniella fragariae
2592	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus pellita Muell.	Leaf Blotch	L	Coniella fragariae
3001	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus pellita Muell.	Leaf Target spot	H	Coniella fragariae
4222	N	Palappilly	Central Nursery Chettikulam	Eucalyptus pellita Muell.	Leaf Spot	M	Coniella fragariae
4225	N	Palappilly	Central Nursery Chettikulam	Eucalyptus pellita Muell.	Leaf Spot	H	Coniella fragariae
1526	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith.	Leaf Spot	L	Coniella
139	P	Nilambur	KFRI Sc campus	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1474	P	Pathanapuram	Kadakam	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1514	P	Pathanapuram	Kaithakettu	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1519	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1523	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1525	P	Pathanapuram	Punnala	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae
1597	P	Kulathupuzha	Kulathupuzha	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1670	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf Blotch	M	Coniella fragariae
1678	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf spot	L	Coniella fragariae
1733	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf spot	M	Coniella fragariae
1739	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf blotch	L	Coniella fragariae
2576	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Concentric Spot	M	Coniella fragariae
2591	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Leaf Spot	H	Coniella fragariae
2596	P	Kulathupuzha	Kandanchira KFDC Plantations	Eucalyptus tereticornis Smith	Leaf Blotch	M	Coniella fragariae
2773	N	Nilambur	Central Nursery Valluvassery	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
3277	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae

3278	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
3886	SEF	Karulai	Pattakarimbu	Eucalyptus tereticornis Smith	Leaf Blotch	H	Coniella fragariae
3887	SEF	Karulai	Pattakarimbu	Eucalyptus tereticornis Smith	Leaf Blotch	H	Coniella fragariae
4234	N	Palappilly	Central Nursery Chettikulam	Eucalyptus tereticornis Smith	Leaf Spot	H	Coniella fragariae
1740	P	Kodanadu	Plamudi	Eucalyptus tereticornis Smith	Leaf spot	L	Coniella fragariae
3280	P	Muthanga	Muthanga	Eucalyptus tereticornis Smith	Leaf Spot	L	Coniella fragariae
1669	P	Kodanadu	Kottapara	Eucalyptus tereticornis Smith	Leaf Blotch	L	Coniella fragariae + Coniella graneti
2995	P	Kulathupuzha	Arippa	Eucalyptus tereticornis Smith	Leaf Tar Spot	H	Coniella granatii
1618	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Blotch	L	Coniella fragariae
1619	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Spot	L	Coniella fragariae
1681	P	Kodanadu	Kottapara	Eucalyptus urophylla Blake	Leaf Blotch	L	Coniella fragariae
3005	N	Kulathupuzha	Kandanchira Central Nursery	Eucalyptus urophylla Blake	Leaf Blotch	H	Coniella fragariae
1321	MDF	Tholpetty	Tholpetty	Fern	Leaf Spot	L	Coniella fragariae
211	MDF	Nilambur	KFRI Sc campus	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	H	Coniella minima
1816	N	Peechi Vazhani	KFRI Silvi Nursery	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	L	Coniella minima
2981	SEF	Anchal	Sangeevani Vanam	Garcinia gummi - gutta (L.) Robs.	Leaf Blotch	H	Coniella minima
2376	EF	Vellikulangara	Anapandam	Gmelina arborea Roxb.	Leaf Spot / Target spot	M	Coniella
3677	MDF	Athirappally	Athirappally	Gmelina arborea Roxb.	Leaf Blotch	H	Coniella fragariae
3775	N	Palappilly	Central Nursery Chettikulam	Holarrhena pubescens (Buch.-Ham.) Wall.ex G. Don	Leaf Spot	H	Coniella
3674	MDF	Athirappally	Athirappally	Leea indica (Burm.f.) Merr.	Leaf Tip Blight	M	Coniella fragariae
2444	MDF	Thundathil	Panthanthodu	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Blotch	M	Coniella
4106	SEF	Goodrickal	Nilakkal	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Target Spot	H	Coniella
1759	MDF	Palappilly	Veluppadam	Macaranga peltata (Roxb.) Muell.-Arg	Leaf spot	L	Coniella australiensis
1566	P/SEF	Kulathupuzha	Arippa	Macaranga peltata (Roxb.) Muell.-Arg.	Leaf Spot	L	Coniella fragariae
4106	SEF	Goodricka	Nilakkal	Macaranga peltata	Leaf	H	Coniella fragariae

		l		(Roxb.) Muell.-Arg	Target Spot		
4342	MDF	Ayyappan kovil	Periyakanal-Anayirangal	Macaranga peltata (Roxb.) Muell.-Arg	Leaf Spot	H	Coniella fragariae
1484	P/MDF	Pathanapuram	Kadakam	Macaranga peltata (Roxb.) Muell.-Arg	Leaf Spot	H	Coniella fragariae
1688	P/MDF	Kodanadu	Kottapara	Mikania micrantha H.B.K.	Leaf spot	L	Coniella fragariae
3683	MDF	Athirappally	Athirappally	Ochlandra travancorica Benth. ex Gamble	Leaf Spot	H	Coniella fragariae
4120	EF	Goodrickal	Chinnakayam	Ochlandra travancorica Benth. ex Gamble	Leaf Target Spot	H	Coniella fragariae
3675	MDF	Athirappally	Athirappally	Persea macrantha (Nees) Kosterm.	Leaf Spot	L	Coniella fragariae
2975	SEF	Anchal	Sangeevani Vanam	Persea macrantha (Nees) Kosterm.	Leaf Gall	L	Coniella frageriae
3283	MDF	Muthanga	Muthanga	Pongamia glabra Vent.	Leaf Tip Blight	L	Coniella
4226	N	Palappilly	Central Nursery Chettikulam	Strychnos nux-vomica L.	Sooty Mould	M	Coniella fragariae
2977	SEF	Anchal	Sangeevani Vanam	Syzygium caryophyllatum (L.) Alston	Leaf Spot	M	Coniella petrakii
3357	EF	Periya	Chandanathodu	Syzygium mundagam (Bourd.) Chitra	Leaf Spot	L	Coniella fragariae
147	MDF	Nilambur	KFRI Sc campus	Tabernaemontana heyneana Wall.	Leaf Spot	L	Coniella fragariae
2697	MDF	Agasthyavanam	Kotoor	Terminalia chebula Retz.	Leaf Spot	M	Coniella fragariae
146	MDF	Nilambur	KFRI Sc campus	Terminalia paniculata Roth	Leaf Spot	L	Coniella fragariae
144	MDF	Nilambur	KFRI Sc campus	Terminalia paniculata Roth	Leaf Spot	L	Coniella fragariae
3891	MDF	Kodanadu	Vembooram	Tetramelus nudiflora R.Br.	Leaf Spot	M	Coniella
1789	SEF	Chimmony	Chimmony Dam	Unidentified host plant	Leaf spot	L	Coniella
3292	EF	Periya	Chandanathodu	Unidentified host plant	Leaf Angular Spot	L	Coniella minima
3609	N	Nilambur	Central Nursery Valluvassery	Vateria indica L.	Leaf Blotch	L	Coniella castaneicola

CONCLUSIONS

The forests in the Kerala part of the Western Ghats support a rich pathogenic fungal flora. The distribution and level of parasitism of various fungi in different forest ecosystems are governed mostly by the climatic and edaphic factors as well as host parasite inter-relationships. Among the forest ecosystems explored, maximum fungal species diversity was observed in forest plantations, which was followed by moist deciduous forests and semi-evergreen forests. Forest plantations support a rich pathogenic fungal flora and the plant - fungal ratio recorded in this ecosystem is as high as 1:14. In moist deciduous forests and semi-evergreen forests, the plant-fungal ratio is 1:3.1 and 1:3.48 respectively. The results show that monoculture plantations and disturbed forest ecosystems support a large number of pathogenic fungi, which cause root, stem, and foliage diseases and thrive well under conducive environmental conditions. Build up of pathogen inoculum occurs over the years and the disease caused by the fungal pathogen may even spread to an epidemic proportion. In forest plantations, eucalypts dominate the system and a single host species (*Eucalyptus tereticornis*) harbors more than 25 genera of pathogenic fungi. This is almost 25% of the total fungal genera encountered in the study. The recently introduced exotic plant, *Acacia mangium* also harbors 21 genera of pathogenic fungi, and was found severely affected with vascular wilt pathogen, *Fusarium solani* and root rot pathogen *Ganoderma lucidum.*

The results show that exotic host species are more vulnerable to the indigenous fungal pathogens and the monoculture plantations serve as reservoir of inoculum of different phytopathogenic fungi. In forest nurseries the plant-fungal ratio is only 1: 3.8. Earlier, conventional seedbed nurseries supported a large number of pathogenic fungi and the recent technological change in the seedling production system using root trainers and high input management in nurseries excluded many nursery pathogens.

Disturbances caused by anthropogenic factors including forest fires seem to be the important factor for incidence and spread of diseases and thereby the increase in

pathogenic fungi. More fungi were encountered in disturbed stands than less disturbed stands in evergreen and wet evergreen forests. In evergreen and wet ever green forests, though fungal pathogens are found causing foliage infections, they are not probably making any serious damage to the systems. Diversity of obligate parasites like rust fungi is found more in evergreen, wet evergreen and semi-evergreen forest.

With regard to the community and species composition, almost same fungal flora was observed in moist deciduous forests, semi-evergreen forests and forest plantations, however, fungal species dominance and abundance occurred depending on the environmental conditions as well as host plants. Among the fungal groups, Mitosporic fungi were found widely distributed in all the forest ecosystems and exhibit wide host range. *Cylindrocladium quinqueseptatum* causing diseases in forest nurseries and eucalypt plantations was found associated with more than 25 indigenous host species in wet evergreen, evergreen, semi-evergreen to moist deciduous forests, which reveals the adaptability of the pathogen in different ecosystems. Pathogenic fungi viz., *Colletotrichum* state of *Glomerella, Curvularia, Phomopsis, Guignardia, Phyllosticta, Calonectria, Corynespora, Fusarium, Myrothecium, Pestalotiopsis, Phoma, Cylindrocladium* and *Coniella* are the most widely distributed ones in different forest ecosystems in the Western Ghats. Monoculture plantations in the Western Ghats serve as reservoir of a large number of phyopathogenic fungi, which may become threat to other crops in due course.

Diversity is a dynamic aspect of ecosystems and whose importance and contributions to system functions are still not well understood. It is well known that listing of fungal species from various ecosystems without attempting to evaluate and understand the dynamic mechanisms that contribute to the observed patterns of total biodiversity is only describing the shadows of the ecological actors that are participating in a complex and interesting evolutionary play. Hence, more in-depth research programmes incorporating current methodologies of sampling designs that account for effects of scale on patterns of fungal biodiversity – both temporal variation and spatial heterogeneity are warranted.

Appendix II: Host Index

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