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Current Insight of Foliicolous Fungi: A Review

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Foliicolous micro-fungi are the microscopic fungi inhabiting leaf surface as asymptomatic mutualists, benign commensals or latent pathogens. The present paper presents a review of foliicolous fungi with complete information from various journals, books, websites and institutions involved. Apart from the addition of a complete list of literature on Indian foliicolous fungi, the future scope of research on foliicolous fungi in India .

Keywords: Foliicolous Fungi, Mycology, Mycological websites and journals

INTRODUCTION

The Kingdom Fungi is one of the most diverse and globally distributed groups of eukaryotes. Fungi evolved with wide morphological, physiological, and ecological heterogeneity that allowed them to perform vital functions in both terrestrial and aquatic ecosystems (Walker and White, 2005; James *et al*. 2020; Li *et al*. 2021). Fungi are now recognized as a polyphyletic assemblage of eukaryotic organisms that are peculiar in their vegetative and reproductive stages. Hence, E. M. Fries, the founder of Systematic Mycology, has rightly, remarked, “Mycology would have collapsed under its own weight if all the species were described”.

Fungi inhabiting living leaves or phylloplanes of plants are considered “foliar fungi”. or “foliclous fungi,” and most of these fungi are obligate or facultative parasites causing lethal effects to the host, residing on the surface of the leaves, producing special organs, and opting for special adaptation; they act necrotrophs or biotrophs, and their infection may lead to the destruction of the plant.

Foliicolous fungi occupy a unique ecological niche to influence the distribution, ecology, physiology, biochemistry, and plant defense mechanisms of the host plants. The biology of these foliicolous fungi is of interest to microbial ecologists as they influence aerial plant surface ecosystems. The distinction among endophytes, epiphytes, and saprophytes is said to be purely academic, and it is difficult to draw limits between the fungi occurring in these ecological groups (Azevedo *et al*. 2002). They reside on the leaf surface and act as asymptomatic mutualists, benign commensals, or latent pathogens. A slight imbalance in this relationship can lead to the pathogenic phase of the fungi. Entry and establishment are the two primary requisites for the pathogen to cause disease. Most fungi grow as hyphae, which are cylindrical, thread-like structures, 2–10 mm in diameter and often upto several centimeters in length. Mycelium forms an interconnected network of hyphae. Hyphae can be either septate or coenocytic. Leaf spot pathogens infect through natural plant openings such as stomata or by penetrating directly through the host cuticle and epidermal cell wall. In order to penetrate directly, fungi produce hydrolytic enzymes such as cutinases, cellulases, pectinases and proteases for breaking down the host tissue. Alternatively, some fungi form specialized structures called appressoria (sing. appressorium) at the end of germ tubes. Turgor pressure builds up in the appressorium, and in combination with an infection peg, mechanical force is exerted to breach the host cell walls. Once inside the plant leaf, the fungus must obtain

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nutrients from the cells, and this is often accomplished by killing host cells (necrotrophs). The death of host cells is evident in an area of dead cells called a lesion. Many leaf-spotting fungi produce toxins that kill host cells, and this often produces a lesion surrounded by a yellow halo. Fungi causing foliar diseases on plants commonly produce reproductive structures such as acervuli, pycnidia, perithecia, or apothecia in association with the necrosis. The life cycle of a typical foliage parasite on trees involves the production of ascomata on infected leaves either during the rainfall or early spring. Ascospores are discharged about the time that the new foliage appears in the spring. The fungus overwinters as a saprobic mycelium or as ascomata in infected leaves or twigs to complete the cycle. Depending on the susceptibility of the host plant, some foliicolous fungi become phytopathogenic and often inflict diseases on plants, resulting in a variety of symptoms, viz., leaf discoloration, leaf blight, leaf sooty spots, leafy shot holes, tar spots, leaf powdery mildew, leaf black mildews, downy mildews, rust, smuts, galls, etc. Some fungi, such as sooty moulds inhabiting leaf surfaces, do not have direct interaction with the host to begin with. It was assumed earlier that these moulds grow upon honey dews deposited by insects, but later it was found that these organisms can also grow beyond the honey dew and draw nutrition from the organic matter deposited on the leaf surface or from leaf exudates. When the leaf spots are numerous and extend all over the surface of the leaf, there is a considerable reduction in the productivity of the host plant. Rapid defoliation that occurs due to leaf-spot diseases also causes a reduction in productivity. These fungal diseases have become important as they dwindle a country's economy by contributing to the biodeterioration or destruction of important plants, resulting in economic losses. The study of fungal diseases was mainly carried out in temperate regions and on agricultural crops. Some of the studies published on tropical plants suggest that many fungal diseases are cosmopolitan in their distribution.

The most abundant fungi on the surfaces of leaves are yeasts belonging to Ascomycetes and Basidiomycetes. The genera *Candida, Cryptococcus, Rhodotorula, Sporobolomyces, Tilletiopsis,* and *Torulopsis* were regularly found on the surface of the leaves. Taxa belonging to filamentous Ascomycetes, the Zygomycetes, Basidiomycetes, and Deuteromycetes have been recorded on the phylloplane of different plants.

THE WORLD OF FOLIICOLOUS FUNGI

Phylloplane fungi have been recorded in several plant species in tropical and temperate ecosystems (Inacio *et al.*2002).

Depending on the susceptibility of the host plant, some fungi become phytopathogenic. Spores settled on the aerial surface of leaves prior to senescence are better positioned to initiate and carry out substrate decomposition. Subsequent studies suggested that an active population of fungi exists on the surface of physiologically active green leaves. All these observations motivated mycologists and plant pathologists to consider phylloplane as a distinct microhabitat for the study of microflora and their dynamics.

Several excellent reviews emphasizing microbial colonization of leaf surfaces or related topics have appeared in recent years (Andrews and Harris, 2000; Hirano and Upper, 2000; Lindow and Leveau, 2002; Lindow and Brandl, 2003). A wide variety of fungi colonize the leaf even before senescence.

Foliicolous mycoflora of a variety of plants have attracted the attention of plant pathologists with a view to exploring the ecological interactions between the pathogenic and the saprophytic fungi with regard to disease interactions. Foliicolous ascomycetes were well documented but the efforts to culture and preserve the foliicolous fungi have so far been very rare. Arrays of studies have been conducted on patterns of colonisation by fungi on leaf surfaces. Generally, three categories are selected to explain the patterns of colonisation of fungi on leaf surfaces.The first category includes those phylloplane inhabitants that are best adapted for life on green leaves. Such fungi are probably able to complete their life cycle or some significant part of it on living leaves and are not expected to be involved in extensive decomposition process. Species of Microthyriaceae, Chaetothyriaceae, and the sooty moulds may develop extensively and over long periods on healthy plants. The second category

includes those phylloplane fungi that grow almost continuously and have vegetative structures that are able to repeatedly alternate between luxuriant growth and survival. *Aureobasidium* and *Cladosporium* form microsclerotia, which are able to withstand desiccation and probably other adverse environmental factors. In addition to these, both may develop hyphal forms on the leaf surface. The third category includes those phylloplane fungi that contend with changes occurring on the surface environment of leaves through rapid and copious reproduction. Efficient spore dispersal and prompt resumption of vegetative growth occur when favourable conditions arrive. *Sporobolomyces* is a good example of a surface-occupying fungus growing quickly when conditions become favorable. Among the well-defined pathogens on leaves, powdery mildew forms a special category of fungi growing completely on the leaf surface.

FACTORS AFFECTING FUNGAL COMMUNITY DEVELOPMENT ON LEAF SURFACES

The leaf surface has long been considered a hostile environment for fungal colonists. Environmental changes, such as CO_2 levels, UV radiation, air pollutants, etc., can affect the milieu of the leaf surface, which in turn can exhibit altered growth and activity of fungal populations. Scientists have pointed out that the season, age of the plant, and nutritional status of the leaf control the nature of Phylloplane mycoflora. Researchers stated that the diversity and density of epiphytic fungi are influenced by factors such as humidity, temperature, incidence of sunlight, nutrient availability, leaf age and type, the presence of inhibitors, and the arrival and settlement of viable propagules. The presence of phylloplane fungi is due to the availability of fungal inocula, the nature of the plant surface, factors such as temperature, rain, dew, humidity, wind, physiology, the health status of the plant, and the nature of the plant community. Researchers have recognized factors such as cell leakage, competition, pollen effect, inter-specific competition, plant inhibitors, and climatic factors as influencing the growth of fungal communities on leaf surfaces. Conceptually, there are several processes that can influence the size and composition of fungal nutrients,some of which are as follows.

- The abundance of nutrients on plant surfaces dictates the population size of various microbes, and it was also found that fungi have the potential to infect plants and draw nutrients directly from the internal cells of the plant rather than relying on the diffusion of nutrients to the plant surface.

- Fungal population sizes on a leaf can increase by both multiplication on that leaf as well as by the immigration of microbes from other leaves. The immigration of microbes to a leaf is strongly coupled to their emigration from another leaf.

- Differences in tissue specificity may also reflect differences among microorganisms in how they enter the leaf or host responses to the presence of microorganisms.

- Forest canopies also affect the development of fungal communities on leaf surfaces. Leaf-colonizing fungi tend to be more numerous on lower leaves and on more peripheral (further from the trunk) leaves in the canopy. The topography of the leaf surface has an effect on the microbial inhabitants, particularly fungi

- On young green leaves, yeasts and yeast-like imperfect fungi such as *Auriobasidium pullulans* and *Cladosporium* are prominent. As the leaf matures, hyphal development increases rapidly and at abscission, the leaf is extensively colonised. It has been observed that the mycoflora changes as senescence occurrs, and to a certain extent, the mycoflora affects the rate of senescence in plants. At the stage of abscission, primary saprophytic species belonging to genera such as *Ascochyta, Leptosphaeria, Pleospora,* and *Phoma,* along with other parasitic fungi, inhabit the leaf.

- Foliage diseases are extremely sensitive to environmental conditions, and higher disease incidence can be expected in years when spring and early summer weather is cool and wet for prolonged periods of time. Leaves in lower crowns and on the north sides of trees are affected more often by the powdery mildews, as they are favoured by shade and dry foliage.

◆ Leaf surfaces have differential spore traps. Their efficiency in trapping depends upon their position and nature, such as: vertical, wet or dry, hairy or glabrous, glossy or mat, waxy or non-waxy. etc.

◆ The role of UV irradiation on microbial communities has been reviewed. Antagonistic interactions are found to be more pronounced in the phylloplane. These interactions among different members of the phylloplane myco-population show considerable importance in maintaining the balance among different organisms.

Many diseases are caused by the foliicolous fungi; with depending upon their appearance, they are termed discoloration, blight, sooty spot, shot hole, tar spot, powdery mildew, black mildews, downy mildews, rust, smuts, and so on.

Leaf spots or leaf blight

The chief symptom of a leaf spot disease is spots on the foliage. The spots vary in size and colour depending on the plant affected, the specific organism involved, and the stage of development. Spots are most often brownish, but they may be tan or black. Concentric rings or dark margins are often present. Spots or blotches that are angular are generally referred to as anthracnose, and leaves turn yellow and drop prematurely. During wet weather, spores may splash or be blown onto newly emerging tender leaves by the wind, which upon attainment of favourable conditions, germinate and infect the leaf. Overhead watering can also provide prolonged wet periods suitable for spreading leaf spot diseases. The following genera of Hyphomycetes (anamorphic ascomycotina) are, in general, considered foliicolous and cause leaf spots (*Cercospora* Fresen*., Cercosporella* Sacc*., Cercostigmina* Braun*, Cercosporidium* Earle*, Corynespora* Gussow*, Gonatophragmium* Deighton*, Helicomina* Olive*, Mycocentrospora* Deighton*, Mycovellosiella* Rangel*, Paracercospora* Deighton*, Passalora* Fr*., Phaeoisariopsis* Ferraris*, Phaeoramularia* Muntanola*, Pseudocercospora* Speg*., Pseudocercosporella* Deighton*, Pseudophamularia* Braun*, Ramularia* Unger*, Stenella* Sydow*, Stigmina* Sacc*., Thedgonia* Sutton.

Among foliicolous fungi, cercosporoid fungi are the most common (Braun *et al*. 2002; Braun and Pennycook, 2003; Braun and Hill, 2004). *Cercospora-Cercosporidium* complex and *Cercosporella-Ramularia* complex are the two major groups forming cercosporoid fungi. Major genera of cercosporoid fungi, such *as Cercospora, Corynespora, Gonatophragmium, Mycovellosiella, Passalora, Phaeoramularia, Pseudocercospora, Pseudocercosporella, Stenella,* etc., are briefly described here. Crous *et al.* (2000) published reviews on *Cercospora,* a generic assemblage. Crous *et al*. (2000) reduced the number of species of *Cercospora* based on molecular studies. Kobayashi *et al*. (2002) and Nakashima *et al.* (2002, 2004) added several species of *Cercospora* to the Japanese mycoflora.

Many species of *Stenella* were described by Chaudhary and Chaudhary (2003). Besides this, the Cercosporoid genera such as *Ramichioridium, Veronaea,* and *Stenella* were studied by Braun and Pennycook (2003). Taxonomic aspects of *Ramularia* were elaborated by Braun and Pennycook (2003). Tripathi and Tripathi (2003) described nine new species of *Gonatophragmium,* viz., *G. semi-lunatum, G. daedalacanthi, G. justiciae, G. jarwarensis, G. lamiacearum, G. pogostemonidis, G. deightonii, G. kushinagarensis,* and *G. moracearum,* from India. Barreto and Marini (2002) described the new species of *Mycovellosiella.*

Powdery Mildews

The Erysiphaceae, or powdery mildews, is a family of Ascomycota. They are obligate parasites nourished by haustoria and develop a characteristic white powdery conidial stage on the leaves and stem surfaces of the host. The lower leaves are the most affected, but the mildew can appear on any part of the plant above ground. As the disease progresses, the spots get larger and denser as large number of asexual spores are formed, and the mildew may spread along the height of the plant. In some powdery mildews, the sexual phase (perithecia) of the fungus is

visible as minute black spheres on the lower surface of the leaves. Infected tissues may be stunted or chlorotic. Powdery mildew fungi overwinter as dormant spores in the protective environment on twigs and leaf debris. Although new leaves become infected as they emerge in the spring, the diseases may not be evident until mid-summer.

Powdery mildews have the greatest diversity in temperate regions. No powdery mildew fungus is known to occur on gymnosperms, pteridophytes, mosses, or liverworts. Foliicolous fungi of Kodaikanal, Tamil Nadu, were studied by Hosagoudar *et al*. (2010).

Sooty moulds

The sooty moulds are a group of over 200 epifoliar fungal species that live on plant surfaces where sap-feeding insects feed on plant foliage. Sooty moulds may form a thin network of hyphae, a velvety growth, or a dark crust on leaves and smaller twigs. They are common on the leaves, twigs, and sometimes fruits of many tropical fruit crops. Some sooty moulds on leaves are found in close association with glandular trichomes. These mould fungi neither infect the plant tissues nor damage the surface. Still, the science of plant pathology treats mould fungi as plant diseases because of their negative effects on photosynthesis (Nelson, 2008; Laemmlen, 2011). Sooty mould-forming fungi mainly belong to the families Antennulariellaceae, Capn-odiaceae, Chaetothyriaceae,Cocc-odin-iaceae, Euantennariaceae,Meta-capno-diaceae, Schifferulaceae, Trichomeriaceae, and several miscellaneous genera (Chomnunti *et al.,* 2012a, 2012b; Hughes and Seifert, 2012; Hyde *et al.,* 2013; Hosagoudar and Riju, 2011). These moulds usually include asexual and sexual stages of the same or different species, although not all sooty moulds produce a sexual state (Hughes and Seifert, 2012). Sooty moulds are well studied at the morphological level, but they are poorly represented in natural classification based on phylogeny. They are common in warm to tropical regions, and the diversity of species is generally higher in warmer climates (Jouraeva *et al.,* 2006; Nelson, 2008; Dhami *et al*. 2013). They occur in most vegetation types around the world but are prevalent around the margins of rain forest communities. Some species of sooty moulds produce as many as three different asexual forms.

Black mildew fungi

Black mildew colonies are scattered, dark, superficial, and circular, produced by the fungi on the surface of their plant hosts. They are most diverse in the tropics and the greatest infection of black mildew occurs in rain forests. Most (>90%) plant hosts are dicotyledons, but black mildews also occur on monocotyledons, gymnosperms, and pteridophytes. Asterinaceous fungi are host-specific in order to be circumventing and tolerant enough to overcome the specific resistance factors of the particular host (Chandra Prabha *et al.* 2011). The species concept of asterinaceous fungi was based on the respective host plants and also on the morphological aspects of the fungus (Hosagoudar, 2012). The biogeographical distribution of Meliolaceae members in India is described and illustrated by Hosagoudar (2003, 2006 a). Hosagoudar and Archana (2007) reported some species of *Asterina* from the Western Ghats region of Peninsular India. Hosagoudar and Robin (2011) studied five new black mildews, namely *Amazonia palaquii, Asterinaleucodis*, *Meliola aporusoe*, *M. gouaniicolo,* and *M. knemae*. Hosagoudar (2013) published a research article, which comprises of 6059 entries from the reprints and gives an account of 2084 fungal taxa belonging to 259 genera on 2969 hosts or substrates. His contributions were mainly based on the black mildew fungi from Satara in Maharashtra, the Nilgiris, Anamalai, Seithur Hills, Kothayar in Tamil Nadu, Kodagu in Karnataka, and most of the places in the Western Ghats of Kerala state. Although Hosagoudar (2008, 2013) compiled all his contributions in Meliolales of India, published in three volumes, Asterinales of India qualifies as a well-studied and illustrated document by Hosagoudar (2012). Dubey *et al*. (2022) studied the taxonomy, distribution, and statistical ecology of black mildew fungi reported from Maharashtra, India.

Galls

Leaf gall symptoms appear soon after flowering and are quite apparent as the leaves become

thickened with a fleshy or leather-like texture and their shape gets distorted. Galls are caused by members of the order Exobasidiales, comprising four families: Exobasidiaceae, Brach-ybasidiaceae, Cryptobasidiaceae, and Graphiolaceae (Bauer *et al*. 2001). In Exobasidiaceae, species of *Exobasidium* are parasitic on Ericales. *Kordyana* affects Commelinaceae, and *Muribasidiospora* causes foliage spots on *Rhus* and *Celtis*. In Brachybasidiaceae, *Brachybasidium* species occur on Palmae; *Proliferobasidium heliconiae is* found on *Heliconia;* and *Ceraceosorus bombacis* is found on *Bombax* (Bombacaceae) in India. The members of the Cryptobasidiaceae are associated with hypertrophied host tissue. Preferred hosts are members of the Lauraceae (Bauer *et al.* 2001). The Graphiolaceae include smut-like organisms pathogenic to palms. The family is exclusively tropical and subtropical in distribution. *Graphiola* species cause premature shedding of leaves in date palms.

Fly-Speck fungi

Fly-speck show dark, flattened, dimidiate-scutate (shield-shaped) ascomata, which appear as small, dark, superficial dots on a leaf surface and are caused by the genera of the family Microthyriaceae of the Ascomycotina.

Tar Spot Fungi

A microscopic sign of the tar spots is the stroma and mats of hyphae found in the form of lesions. *Rhytismaacerinum* (teleomorph) and *Melasmia-acerina* (anamorph) produce only on the upper surfaces of leaves in spring.

Hypertrophic symptoms (Galls, witches brooms)

Hypertrophic symptoms (galls, witches brooms) are caused by Taphrinales and Protomycetales, the two closely related orders of Ascomycotina. The Taphrinales are represented by one genus, *Taphrina*, with about 189 recognised species. *Taphrina* species are biotrophic microfungi that occur on ferns or higher plants, often causing hyperplasia and the formation of galls or witches' brooms. The Protomycetales include one family, Protomycetaceae, which contains six genera. The largest genus, with about 100 recognised species, is *Protomyces*, a predominately temperate-region fungus that causes gall formation in leaf and stem tissues.

Needle-cast fungi

Needle-cast diseases are caused by members of the Rhytismataceae (Ascomycotina). It occurs in temperate regions where conifers (gymnosperms) are common. Species commonly causing needle blights and casts on conifers are members of genera such as *Lophodermium*, *Lophodermella*, *Elytroderma*, *Hypodermella,* and *Lirula*, which often produce symptoms such as chlorotic, discoloured foliage, and repeated defoliation.

Leaf rust fungi

Rust fungi are one of the most speciose and complex groups of plant pathogens belonging to the order Pucciniales (formerly Uredinales) of subdivision Pucciniomycotina (Aime, 2006; Aime and McTaggart, 2020; Gautam *et al*. 2021). The rust fungi are obligate plant parasites that share relatively similar life cycles, morphology, and biology. Generally, the majority of rust fungi require two unrelated, specific plant hosts to complete their life cycle, i.e., heteroecious types. The fungi comprise a broader host range, extending from lower plants like ferns to higher plants including angiosperms and gymnosperms. These fungi commonly appear as a yellow-orange or brown powdery mass on healthy and vigorously growing plant parts such as leaves, petioles, tender shoots, stems, and fruits. These fungi possess several unique systematic characteristics (Duplessis *et al*. 2011). A single species of rust fungi may produce distinct spore-producing structures (up to five) during their life cycle. The diverse structures, viz., Spermogonia, Aecia, Uredinia, Telia, and Basidia, are produced in successive stages of reproduction during the infection process and may vary from species to species (Cummins and Hiratsuka 2003; Duplessis *et al*. 2011).

According to the accepted estimation, rust fungi bring together 168 genera and approximately 7000 species, out of which more than half belong

to the genus *Puccinia*. The majority of species in temperate regions are well catalogued, but many new genera and species are perceptibly expected from tropical and subtropical regions. They reported that potential hosts of rust diseases come from a broad range of vascular plant families, including ferns, gymnosperms, monocots and dicots. No rusts have been reported from mosses or liverworts, but related small genera of heterobasidiomycetes, such as *Iola, Platycarpa*, and *Ptechetelium*, are parasites on mosses and ferns. Significant contributions have been made by different workers (Mohanan, 2010; Deising *et al.* 2000; Voegele and Mendgen, 2003; Marsalis and Goldberg, 2006; Wallis and Lewandowski, 2008).

Gautam *et al*.(2021)reported 69 genera and 640 species of rust fungi belonging to 16 families from India. Mahadevakumar *et al*. (2016) described a new species of rust fungus, i.e., *Puccinia mysuruensis*, associated with wild coffee (*Psychotria nervosa*) in India. Considerable contribution is made by Aggarwal *et al*. (2017a, b) in the area of gene based analysis of *Puccinia*. Recently, a new report of *Chrysanthemum* rust in Karnataka was reported by Somasekhara and Chandramohan (2015) and in Kerala by Mohanan, (2010). Coffee leaf rust is another important disease, along with other major rust diseases, being investigated by Indian mycologists and pathologists (McCook, 2006; Narayana, 2012, 2013). Some new species of rust fungi along with a few new records were also added by Gautam and Avasthi (2016), 2017 (a, b, c) and 2018.

Leaf smut fungi

The smut fungi (Ustilaginales, Ustilaginomycetes, and Basidiomycota) are obligate biotrophic plant parasites that infect hosts belonging to grasses, sedges, and many other plant groups. (Bauer *et al.* 2001). Interestingly, they are almost absent in primary forest regions.Smut fungi are the second largest group of phytopathogenic fungi after rusts, with approx. 1450 species in about 77 genera (Vánky, 2007a, b; Wijayawardene *et al*. 2018; 2020). About 189 host plant species belonging to eight families are reportedly infected by smut fungi, with Poaceae being the most infected (Gautam *et al*. 2021). In India, about 329 species of smut fungi arefound, out of which only 35 species were reported from East and North-Eastern India (Bag and Agarwal, 2001). Sir E. J. Butler made seminal contribution to the research on mycology and plant pathology, including smut fungi in India. After him, many scientists contributed to the understanding of Indian smut fungi with main contributions from B.B. Mundkur, A.R. Patil, B.V. Patil, J.N. Mishra, J.H. Mitter, M.S. Patil, M.S. Pavgi, M.J. Thirumalachar, R.N. Tandon, S.D. Patil, T.M. Patil, and T.S. Ramakrishnan. Dr. K. Vánky also dealt with a number of smut fungi in India. Vikas *et al*. (2020) reported a smut disease caused by *Tranzscheliella hypodytes* (Schltdl.) Vanky and McKenzie *on Leymus secalinus* (Georgi) Tzvelev. The occurrence of a smut fungal genus, namely *Clinoconidium,* was confirmed by Jayawardena *et al*. (2020). A taxonomic revision based on molecular data of *Ustilago, Sporisorium,* and *Macalpinomyces,* carried out by McTaggart *et al*. (2012).

Other groups of foliicolous fungi

Living leaves are colonized by a large and diverse group of fungi. Those fungi are distributed widely, occurring on a wide range of plants in different climates. Among the earliest colonisers of angiosperm leaves are yeasts. Red yeasts in the genera *Sporobolomyces* and *Rhodotorula* and white yeasts, including *Cryptococcus* species, are common. Common leaf-spot-causing microfungi in tropical, subtropical, and temperate regions include species of *Alternaria*, *Ascochyta*, *Cercospora*, *Cladosporium*, *Corynespora*, *Phyllosticta*, *Pestalotia*, and *Pestalotiopsis.*

Parasitic fungi occurring on grasses found in temperate regions include the Ascomycetes belonging to *Gaeumannomyces*, *Gibberella*, *Monographella*, *Phyllachora,* and *Pleospora* (*Stemphylium* anamorphs), as well as the specialised groups of pathogens previously noted. The common hyphomycetous fungi on grasses include *Alternaria*, *Cladosporium, Drechslera, Fusarium, Pseudocercosporella, Hynchosporium,* and *Ulocladium* species. Coelomycetes commonly found on grasses include *Ascochyta* and *Colletotrichum*. Common

foliar parasites of grasses in tropical regions include species of *Cercospora, Drechslera, Magnaporthe, Rhynchosporium, and Sphaerulina. Pyricularia* species are particularly important in the tropics as parasites of rice, other cereals, and grasses. The fungus also parasitizes more than 50 other species of grasses and sedges.

CONTEMPORARY REPORTS OF FOLIICOLOUS FUNGI FROM INDIA

The diversity, distribution, and taxonomy of foliicolous fungi from the Terai forests of Uttar Pradesh were recently accomplished by Shambhu Kumar *et al*. (2015). Mall *et al.* (2013) have also conducted a study of foliicolous fungi in the Terai forests of Uttar Pradesh, India. Studies on powdery mildews, rusts, and smuts are mainly carried out in Himachal Pradesh. The enumeration of powdery mildew, smut fungi, and the status of rust fungi are studied and published by Gautam and Avasthi (2017 a, b, c) and Gautam *et al*. (2021 a,b), Gautam *et al*. (2021 a,b), respectively. The diversity of powdery is studied and a checklist with 92 mildew species is provided by Gautam and Avasthi (2018 a, b). A check list of rust fungi with 167 species belonging to 23 genera was published with new additions and some rediscoveries by Gautam and Avasthi (2019). In recent years. spradic studyes have been done on the foliicolous fungi of West Bengal; however, some cercosporoid fungi have been studied by Haldar (2017a,b). Sabeena *et al*. (2018) have studied some species of foliicolous fungi from the Andaman and Nicobar Islands.

Considerable studies on foliicolous fungi with have been carried out in Kerala by Mathew (2019); Hina and Jacob (2020);Sabeena *et al*. (2020); Lini (2021); Sabeena and Biju (2022) and Lini (2022). The foliicolous fungi of Kerala are well documented by Hosagoudar and his students (Hosagaudar and Robin, 2011). Studies on foliicolous fungi from the Achankovil forests in Kollam district of Kerala state, India, were conducted by Hosagoudar *et al.* (2010). Hosagoudar and Biju (2013) studied "Foliicolous fungi of Silent Valley National Park", Kerala, India. Murugan *et al.* (2016) have worked on the groups of fungi inhabiting leaves. A respectable with amount of work on foliicolous fungi has also been conducted in Central India. Recently, Singh *et al*. (2015) described two species of *Alternaria, i.e., A. smilacearum and A. solitarium,* on living leaves of *Smilax purhampus* Ruiz and *Ficus religiosa* L., respectively, from Sagar, Madhya Pradesh. A highly regarded work has been conducted in the Western Ghats of India on biodiversity, biological distribution, and taxonomy of microfungi (D'Souza, 2002; Prabhugaonkar, 2011; Pratibha *et al*. 2010). The foliicolous fungi of Goa and its adjoining areas were studied by Jalmi (2006). Thimmaiah *et al*. (2013) conducted a systematic survey of the foliicolous fungi of Kodagu, Karnataka.

Kamal (2010) has published a book with comprehensive account of Cercosporoid fungi occurring in India. Kumar *et al*. (2007, 2008, 2012 a, 2012b, 2013) and Kumar and Singh (2016a, b, c) have elaborately studied the genus *Corynespora* mainly from Uttar Pradesh. Singh *et al*. (2012 a, b, c; 2013, 2014, 2019, 2021, 2022) contributed to the phylogeny and taxonomy of Cerocosporoid fungi occurring in Uttar Pradesh while Sinha *et al*. (2022) updated the current status of Cerocosporoid fungi in India. Muthumary (2013) published comprehensive account on Coelomycetes of India.

Noteworthy studies on biodiversity and taxonomy of pathogenic fungi have been conducted by Manoharachary *et al*. (2005), Manoharachary and Kunwar (2014) and Manoharachary and Nagaraju (2021). An exhaustive compilation of Bilgrami's Fungi of India is published by Manoharachary *et al*. (2022) is an asset to Indian Mycology and a ready reckoner for the researchers. Researchers at National Fungal Culture Collection of India (NFCCI) and Agarkar Research Institute of Pune studied the fungi occurring on various plants in the forests of the Western Ghats and documented a number of fungi, including new genera and species (Rajeshkumar *et al.*, 2011, 2012; Singh *et al.,* 2009). Recently, Dubey and Pandey (2017, 2019, 2022 a, b, 2023) published a holistic account of foliicolous fungi from different regions of Maharashtra by integrating fungal taxonomy with statistical analysis of ecological aspects. In Maharashtra, although serious efforts were not made to document the foliicolous fungi

exclusively, studies carried out in an earlier instance revealed the distinct presence of fungi on leaves (Sawant and Papdiwal, 2007; Singh *et al*. 2011).

The present paper is based on the critical analysis of data obtained from different sources and the data published by various research workers, books, monographs, scientific reports, and online databases maintained by websites on mycology. A consolidate account of foliicolous fungi based on the disease symptoms of fungi is provided in this paper. Although, a lot of scope is still present in investigating foliicolous fungi, the current pace of research needs to be accelarated further. The review presented in this study will help in understanding the overview of foliicolous fungi.

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