

New Fungal Records on *Dendrocalamus strictus* from India

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Abstract: Despite being potentially significant, bamboos are susceptible to various fungal diseases. A number of fungi flourish on live as well as dead substrates of bamboo and adversely affect its parts and colonize, gradually causing its degradation. A total number of 73 fungal species were isolated and identified from the diseased culms and foliage of *Dendrocalamus strictus* germplasms comprising 61 provenances from 17 different states of India established in New Forest Campus, Dehradun, Uttarakhand. Among them, major species belong to phylum Ascomycota (62) and rests belong to three phyla, Basidiomycota (6), Zygomycota (4) and Oomycota (1). 23 fungal species were recorded for the first time on *D. strictus* and 38 fungal species, recorded in association with *D. strictus* in earlier reports, were found to be affecting different part of the host. The present study investigates the fungal diseases and their causal organisms of *D. strictus* and surveyed consecutively for two years in monsoon season, which harbors a galaxy of fungi in rhizomes, culms and foliage. Disease Incidence during the survey was also recorded.

Keywords: Ascomycetes, bambusicolous fungi, *Dendrocalamus strictus*, fungal diversity

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Introduction

Bambusicolous fungi or “fungorum bambusicolorum” are familiarized as any fungal entity growing on any bamboo substrate including culms, rhizomes, roots and leaves (Hino, 1938). Many of the bambusicolous fungi are parasitic, however saprobes that degrade bamboos cannot be opted out of sight. *Dendrocalamus strictus* (Roxb.) Nees, a major bamboo species known specially for its strong culms, is found throughout India and well adapted to diverse climate conditions (Tewari, 1992). Despite its utilization in research, agroforestry, reclamation, pharmaceuticals and as building material, it is prone to attack by microbes and insect pests. The biological decay of bamboos is caused due to its high sugar and starch components which serve as excellent source of nutrition for microbes and insects. The attack on culms is largely affected by fungi which cause rotting and staining (Guha and Chandra, 1979).

The prominent fungal diseases in plantations, natural stands, nurseries and storage bamboos are accounted to be culm diseases (rot of emerging and growing culm, culm stain, culm spot), foliar diseases (leaf spot, leaf rust and leaf blight), rhizome diseases (rhizome rot) and sheath diseases (sheath rot and sheath spot). In addition, witches broom, seedling wilt, damping off, culm blight, sooty mold and smut diseases are also recorded (Mohan, 2002).

A number of diseases on *D. strictus* have been reviewed in nurseries as well as bamboo stands from different countries in Asia. For instance, leaf

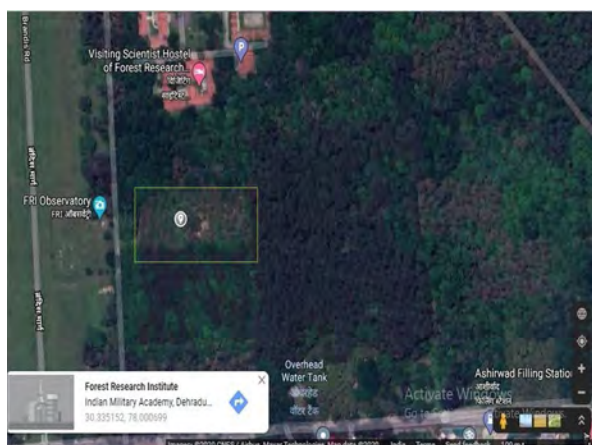


Fig 1. Germplasm bank located at Forest Research Institute, Dehradun, Uttarakhand

rust in seedlings of *D. strictus* by *Dasturella divina* was reported by Mundkur and Kheswala (1943) in Jabalpur, India. Cummins (1971) reported leaf rust on *D. strictus* caused by *Uredo dendrocalami* (Petch) in Sri Lanka. Singh and Pandey (1971), Bakshi *et al.*, (1972) and Patil *et al.*, (1980) reported foliage rust caused by *Tunicospora bagchii* from India. Tar spot caused by *Phyllachora dendrocalami* was reported for the first time by Awati and Kulkarni (1972). Harsh *et al.*, (1989) reported leaf spot caused by *Exserohilum rostratum* (Dresch.) Leonard. Balakrishnan *et al.*, (1990) reported leaf spot caused by *Aschochyta dendrocalami* in natural stands of *D. strictus* from Kerala, India. Azmy and Maziah (1990) reported leaf spot in 10 month-old bare root seedlings caused by *Colletotrichum gloeosporoides* (Penz.) Sacc. in Malaysia. Rot of emerging culm caused by *Rhizoctonia sp.* was first reported by Sheikh *et al.*, (1978) in Pakistan. The workers also reported rhizome and root rot caused by *Polyporus sp.* Tahir *et al.*, (1992) reported rhizome and root rot caused by *Amyloporus campbelli* in MP, India. An extensive review was compiled by Mohanan (2002) highlighting the diseases of bamboos in Asia in International Network for Bamboo and Rattan (INBAR) report. Importantly, from 1990, microbial diseases of different bamboo species, their respective causal organisms, affected host's part and the control measures are thoroughly described in the manual. A recent annotated checklist on bambusicolous fungi was prepared by Remadevi *et al.*, (2017) documenting 432 microbes associated with bamboos from 12 different phyla. Given this background, the

present study aimed to identify the various fungi associated with *D. strictus*.

Materials and Methods

Disease Survey and Data Collection

Disease surveys were conducted in the germplasm bank (Fig. 1) of *D. strictus* which consists of clumps from 61 provenances collected from 17 Indian states established at Forest Research Institute, Dehradun, Uttarakhand in 2008 and funded under National Bamboo Mission project. The geographical location of the germplasm bank is 30.335152N and 78.000699E. It receives an annual rainfall of 1896 mm and favors sub-tropical climate. Sampling was done during July to October for two consecutive years (2015-2016) for observation of culm, rhizome and foliar diseases (Fig. 2). Percent Disease Incidence was calculated. Detailed morphological analysis was done for the identification of fungi.

Isolation and Identification of Fungi

The disease samples were brought to the laboratory for further isolation and identification of fungi. Portions of diseased samples were cut, surface disinfected with 0.1% NaOCl, further inoculated in Potato Dextrose Agar (PDA) Petri dishes and incubated at 25±2°C in BOD incubator for 3-5 days (Dhingra and Sinclair, 1985). Fungi were identified on the basis of their morphological and microscopic characteristics given in standard manuals, monographs and taxonomic papers (Ainsworth *et al.*, 1972; Barnett



Fig 2. Fungal diseases of *D. strictus* in germplasm bank; Leaf blight (a); Leaf rust (b); Leaf spot (c); Rot of emerging culm (d); Rot of growing culm (e); Culm stain (f); Culm spot (g); Root rot (h); Culm blight (i); Sheath blight (j); Macro fungi on decayed culms (k-n)

and Hunter 1972; Booth, 1971; Ellis, 1971, 1976; Gilman, 1957; Grove, 1967).

Results and Discussion

Out of 73 fungal species isolated and identified from the diseased culms and foliage of *D. strictus*, 23 fungi were recorded for the first time. The new records includes *Aureobasidium* sp., *Botryotrichum* sp., *Chalaropsis* sp., *Crepidotus* sp., *Cunninghamella bertholletiae*, *Gloeosporium* sp., *Gliocladium roseum*, *Graphium* sp., *Hygrocybe miniata*, *Leucoagaricus* sp., *Macrohomina phaseolina*, *Marasmius hematecephalus*, *Monilinia fructicola*, *Mortierella elongata*, *Paecilomyces lilacinus*, *Pestalotiopsis adusta*, *Pestalotiopsis theae*, *Phyllosticta* sp., *Pythium aphanidermatum*, *Rhizopus stolonifer*, *Trichothecium roseum*, *Verticillium dahliae* and *Verticillium lecanii*. (Table 1, Fig.3). Ascomycetes group with 84.93% of the total mycoflora emerged out to be the major fungal group

followed by Basidiomycetes (8.22%), Zygomycetes (5.48%) and Oomycetes (1.37%). Although certain fungal species were recorded in association with *D. strictus* in earlier reports but in the present study, they were found to be affecting different part of the host viz. *Acremonium* sp., *Alternaria alternata*, *Alternaria brassicicola*, *Alternaria chlamydospora*, *Alternaria cumini*, *Alternaria phragmospora*, *Alternaria triticina*, *Arthrrium* sp., *Aspergillus flavus*, *Aspergillus nidulans*, *Aspergillus niger*, *Aspergillus tamari*, *Aspergillus versicolor*, *Chaetomium globosum*, *Cladosporium cladosporioides*, *Cladosporium fusiforme*, *Cladosporium herbarum*, *Cladosporium sphaerospermum*, *Colletotrichum clavatum*, *Colletotrichum truncatum*, *Curvularia chlamydospora*, *Curvularia lunata*, *Epicoccum nigrum*, *Fusarium chlamydosporum*, *Fusarium flocciferum*, *Fusarium graminearum*, *Fusarium oxysporum* *Mucor* sp., *Nigrospora bambusae*, *Nigrospora oryzae*, *Nigrospora sphaerica*, *Penicil-*

Table 1. Fungal species and disease incidence on *D. strictus* in germplasm bank

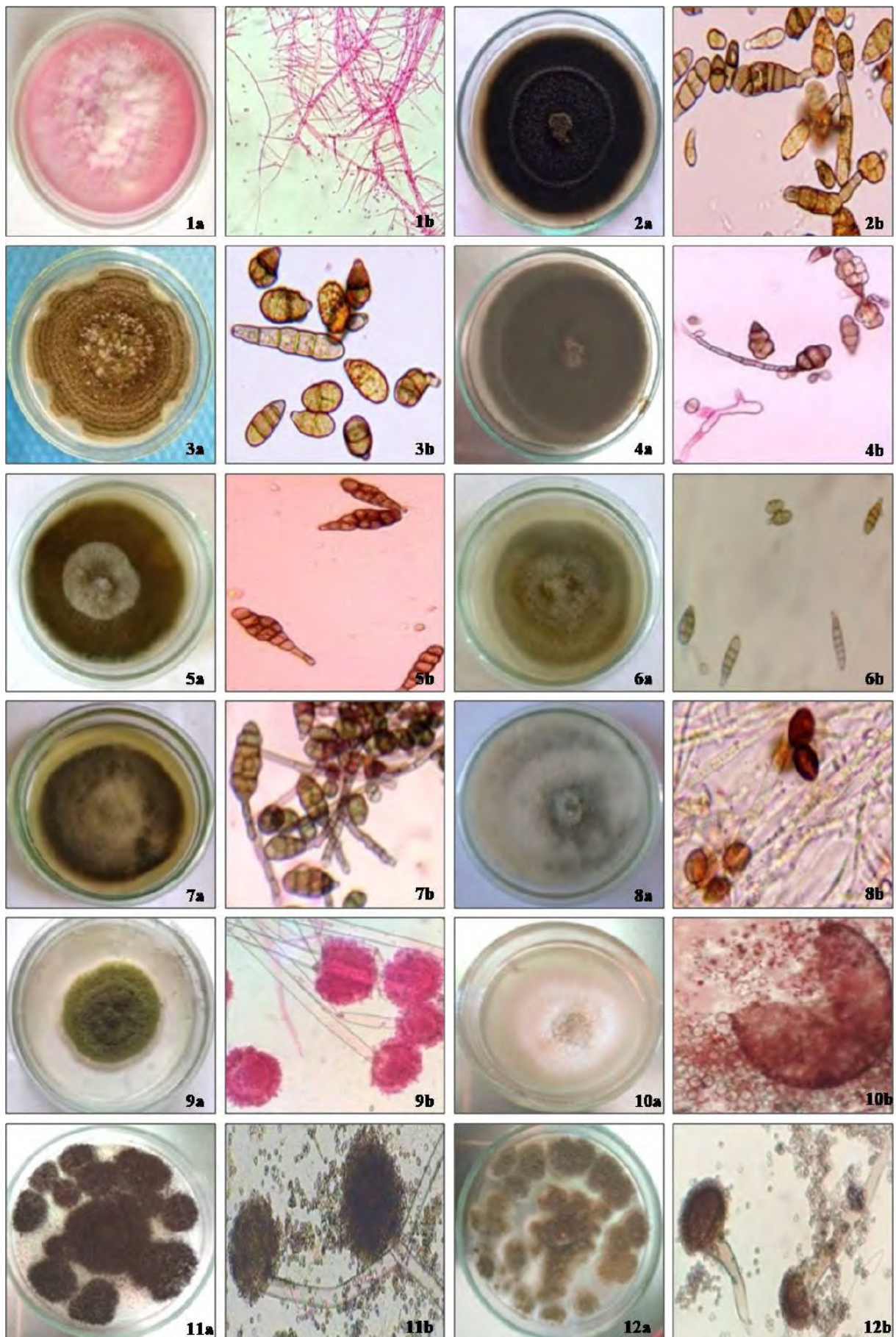
Sl. No.	Fungal Species	Disease*	Disease Incidence (%)		Earlier Disease reports on <i>D. strictus</i> from India
			2015	2016	
Phylum: Ascomycota					
1.	<i>Acremonium</i> sp.	Culm stain	2.81	1.94	Seed (Jamaluddin,1992; Tewari, 1992; Mohanan, 2002)
2.	<i>Alternaria alternata</i> (Fr.) Keissl.	Culm blight, Leaf blight	3.46, 32.40	5.83, 35.21	
3.	<i>Alternaria brassicicola</i> (Schwein.) Wiltshire	Leaf blight	8.86	13.61	
4.	<i>Alternaria chlamydospora</i> Mouch.	Leaf spot	7.56	6.05	Seed, leaf tip blight, leaf spot (Jamaluddin, 1992; Tewari, 1992; Mohanan, 2002, 2006, 2008); Fungi on foliage (Rangaswami <i>et al.</i> , 1970)
5.	<i>Alternaria cumini</i> E.G. Simmons	Leaf spot	2.59	4.10	
6.	<i>Alternaria phragmospora</i> Emden	Leaf blight	16.63	11.02	
7.	<i>Alternaria triticina</i> Prasada & Prabhu	Leaf blight	1.94	2.59	
8.	<i>Arthrimum</i> sp.	Culm blight	1.51	0.65	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 2002)
9.	<i>Aspergillus flavus</i> Link	Culm stain	8.64	6.70	
10.	<i>Aspergillus nidulans</i> (Eidam) G. Winter	Culm spot	0.65	1.51	
11.	<i>Aspergillus niger</i> sp.	Culm stain, Culm spot	30.02, 3.89	21.81, 6.48	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 2002)
12.	<i>Aspergillus tamarii</i> Kita.	Culm stain	1.94	0.43	
13.	<i>Aspergillus versicolor</i> (Vuill.) Tirab.	Culm spot	4.32	3.02	
14.	<i>Aureobasidium</i> sp.	Culm stain	0.22	0.00	New host record
15.	<i>Bipolaris maydis</i> (Y. Nisik. & C. Miyake) Shoemaker	Leaf spot	4.75	2.81	Foliage blight (Harsh et al., 1989); Leaf blight (Mohan, 2006, 2008)
16.	<i>Botryotrichum</i> sp.	Culm spot	0.43	0.00	New host record

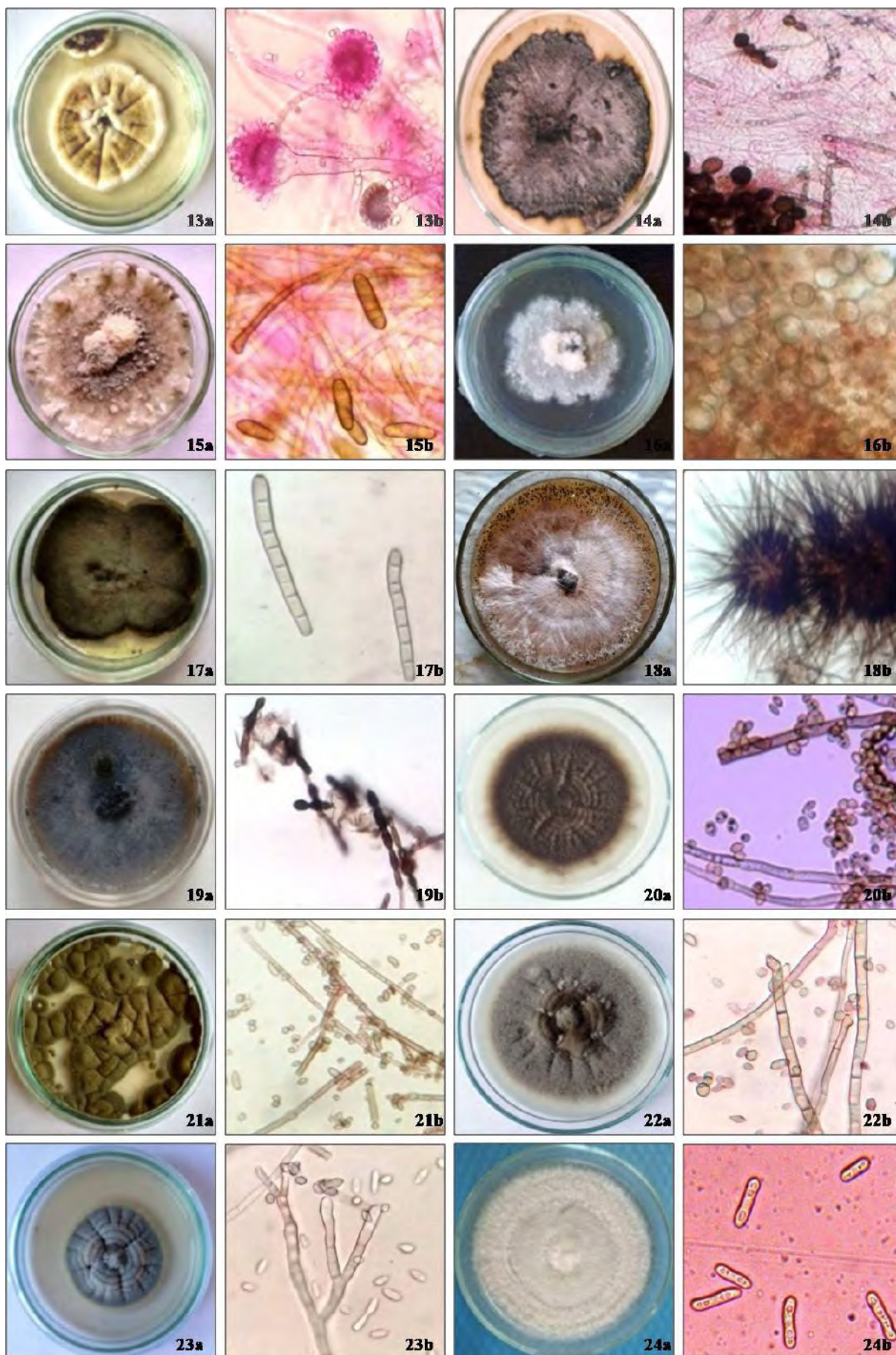
17.	<i>Cercospora</i> Fresen. ex Fuckel	Leaf spot	2.38	1.73	Fungi on foliage, leaf blight (Jamaluddin, 1992; Tewari, 1992; Khan <i>et al.</i> , 1995; Rai and Mamatha, 2003)
18.	<i>Chaetomium globosum</i> Kunze ex Fr.	Rot of growing culm	1.30	0.86	Seed (Mohan, 1988)
19.	<i>Chalaropsis</i> sp.	Culm spot	0.65	1.08	New host record
20.	<i>Cladosporium cladosporioides</i> (Fresen.) G.A. de Vries	Culm stain, culm sheath blight	38.23, 6.05	34.13, 7.13	
21.	<i>Cladosporium herbarum</i> (Pers.) Link	Culm sheath blight	2.16	2.59	Seed (Jamaluddin, 1992; Tewari, 1992; Mohan, 1988, 2002)
22.	<i>Cladosporium fusiforme</i> Zalar, de Hoog & Gunde-Cimerman	Leaf blight	3.67	1.94	
23.	<i>Cladosporium sphaerospermum</i> Penz.	Leaf spot	1.51	0.43	
24.	<i>Colletotrichum clavatum</i> Agosteo, Faedda & Cacciola	Culm sheath blight	1.94	2.59	Leaf spot and leaf blight (Tewari, 1992; Mohan, 1988, 2002, 2006, 2008), Fungi on culm (Jamaluddin, 1992)
25.	<i>Colletotrichum gloeosporioides</i> (Penz.) Penz. & Sacc.	Leaf spot	4.75	6.26	
26.	<i>Colletotrichum truncatum</i> (Schwein.) Andrus & W.D. Moore	Leaf spot	1.08	1.73	
27.	<i>Curvularia chlamydospora</i> Madrid, Da Cunha, Gene & Guarro	Leaf spot	1.08	0.43	
28.	<i>Curvularia lunata</i> (Wakker) Boedijn	Leaf spot	18.14	29.37	Seed (Jamaluddin, 1992; Tewari, 1992; Mohan, 2002), Leaf spot (Mohan, 1988)
29.	<i>Curvularia pallescens</i> Boedijn	Leaf spot	4.97	8.64	
30.	<i>Cylindrocarpon obtusisporum</i> (Cook & Harkn.) Wollenweb.	Rot of emerging culm	0.43	0.00	New host record

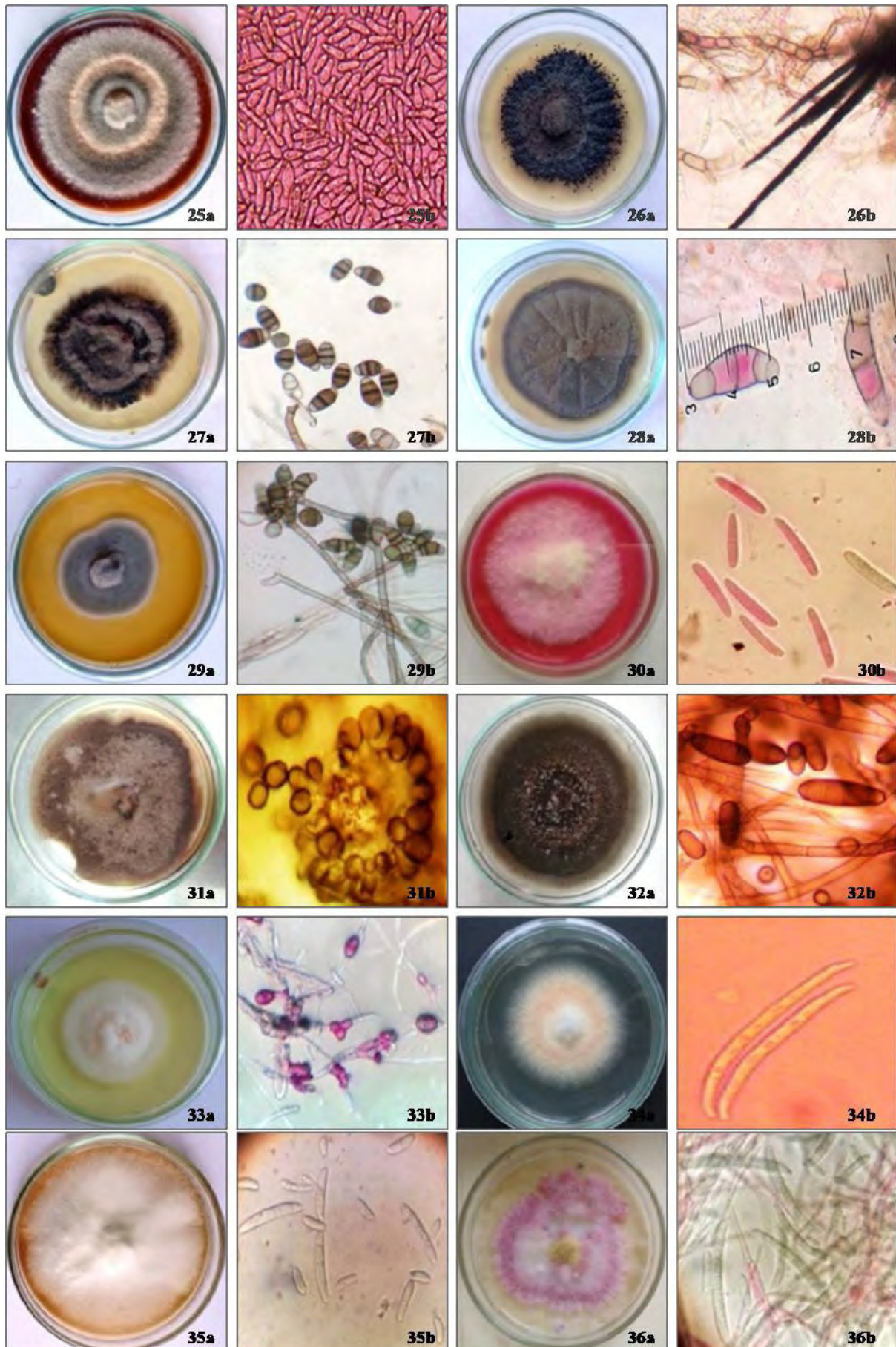
31.	<i>Epicoccum nigrum</i> Link	Culm stain	3.24	1.30	Seed (Tewari, 1992; Mohanan, 1988, 2008)
32.	<i>Exserohilum rostratum</i> (Dreschler) K.J. Leonard & Suggs	Leaf spot	1.73	0.65	Leaf spot (Harsh et al., 1989; Mohanan, 1994, 2002, 2006, 2008)
33.	<i>Fusarium chlamydosporum</i> Wol- lenw. & Reinking	Leaf blight	1.51	0.43	
34.	<i>Fusarium equiseti</i> (Corda) Sacc.	Rot of growing culm	0.86	1.51	
35.	<i>Fusarium flocciferum</i> Corda	Rot of emerging culm	8.86	12.10	Rot of growing culm (Mohanani, 2002, 2006, 2008); Damping-off and Rot of emerging culm (Mohanani 1988, 2006; Tewari, 1992); Branch die-back (Mohanani 2002, 2006); Seedling wilt (Tewari, 1992), leaf spot (Mohanani 2002, 2006), Fungi on culm (Shukla et al., 1988) and on rhizome (Jamaluddin, 1992)
36.	<i>Fusarium graminearum</i> Schwabe	Rot of emerging culm	0.43	0.00	
37.	<i>Fusarium oxysporum</i> Schltdl.	Rot of emerging culm	4.54	6.05	
38.	<i>Fusarium semitectum</i> Berk. & Revenel	Rot of growing culm	0.65	0.22	
39.	<i>Gleosporium</i> sp.	Leaf blight	0.86	0.43	New host record
40.	<i>Gliocladium roseum</i> var. <i>viride</i> Rall	Culm spot	7.78	6.26	New host record
41.	<i>Graphium</i> sp.	Leaf spot	1.51	0.43	New host record
42.	<i>Helminthosporium oryzae</i> Breda de Haan	Leaf spot	2.81	1.51	Leaf blight (Tewari,1992) and leaf spot (Mohanani,1988)
43.	<i>Macrophomina phaseolina</i> (Tassi) Goid.	Root rot	1.08	0.43	New host record
44.	<i>Monilinia fructicola</i> (G. Winter) Honey	Rot of growing culm	1.30	0.00	New host record
45.	<i>Nigrospora bambusae</i> Mei Wang & L. Cai	Leaf spot	14.04	17.06	
46.	<i>Nigrospora oryzae</i> (Berk. & Broome) Petch	Leaf spot	3.67	1.94	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 1988, 2002)
47.	<i>Nigrospora sphaerica</i> (Sacc.) E.W. Mason	Leaf spot	2.38	0.65	

48.	<i>Paecilomyces lilacinus</i> (Thom) Samson	Culm stain	28.94	26.35	New host record
49.	<i>Penicillium chrysogenum</i> Thom	Culm stain	25.70	17.28	
50.	<i>Penicillium digitatum</i> (Pers.) Sacc.	Culm stain	9.94	11.88	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 1988, 2002; D'souza and Bhat, 2013)
51.	<i>Penicillium notatum</i> Westling	Culm spot	4.10	3.67	
52.	<i>Periconia cookei</i> E.W. Mason & M.B. Ellis	Rot of emerging culm	1.73	1.08	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 1988, 2002; D'souza and Bhat, 2013)
53.	<i>Pestalotiopsis adusta</i> (Ellis & Everh.) Steyaert	Leaf spot	10.58	4.75	New host record
54.	<i>Pestalotiopsis theae</i> (Sawada) Steyaert	Leaf blight	15.98	9.29	
55.	<i>Phomopsis</i> sp.	Leaf spot	1.94	0.86	Leaf spot (Mohanani 2002, 2006)
56.	<i>Phyllosticta</i> sp.	Leaf spot	2.59	1.30	New host record
57.	<i>Trichoderma harzianum</i> Rifai	Culm spot	14.69	15.55	
58.	<i>Trichoderma koningii</i> Oudem.	Culm stain	4.97	6.70	Seed (Jamaluddin, 1992; Tewari, 1992; Mohanan, 2002)
59.	<i>Trichoderma viride</i> Pers	Culm stain	1.73	0.65	
60.	<i>Trichothecium roseum</i> (Pers.) Link	Culm stain	5.40	6.70	New host record
61.	<i>Verticillium dahliae</i> Kleb.	Culm stain	18.36	15.55	
62.	<i>Verticillium lecanii</i> (Zimmerman) Viegas	Culm stain	5.18	3.46	New host record

Phylum: Basidiomycota					
63.	<i>Crepidotus</i> sp.	Decayed culm	8 sporocarps	11 sporocarps	New host record
64.	<i>Dasturella divina</i> (Syd.) Mundk. & Khesw.	Leaf rust	65.01	68.90	Foliage rust (Mundkur and Kheswala, 1943; Bakshi and Singh, 1967; Khan <i>et al.</i> , 1995) Leaf rust (Bakshi <i>et al.</i> , 1972; Hosagoudar, 1985; Mohanan, 1988, 2002, 2006; Bhat, 1992)
65.	<i>Hygrocybe miniata</i> (Scop.) MuRoot	Decayed culm	6 sporocarps	13 sporocarps	New host record
66.	<i>Leucoagaricus</i> sp.	Decayed culm	23 sporocarps	15 sporocarps	New host record
67.	<i>Marasmius hematocephalus</i> Kosonen	Decayed culm	3 sporocarps	2 sporocarps	New host record
68.	<i>Rhizoctonia solani</i> J.G. Kuhn	Root rot	2.16	1.08	Damping-off, seedling spear rot and seedling wilt (Mohan, 1988, 2002; Tewari, 1992)
Phylum: Zygomycota					
69.	<i>Cunninghamella bertholletiae</i> Stadel	Culm stain	36.07	27.65	New host record
70.	<i>Mortierella elongata</i> Linnem.	Culm stain	2.38	0.43	New host record
71.	<i>Mucor</i> sp.	Culm stain	19.65	13.61	Seed (Mohan, 1988, 2002)
72.	<i>Rhizopus stolonifer</i> (Ehrenb.) Vuill.	Culm stain	12.74	6.91	New host record
Phylum: Oomycota					
73.	<i>Pythium aphanidermatum</i> (Edson) Fitzp.	Rot of emerging culm	0.22	0.00	New host record







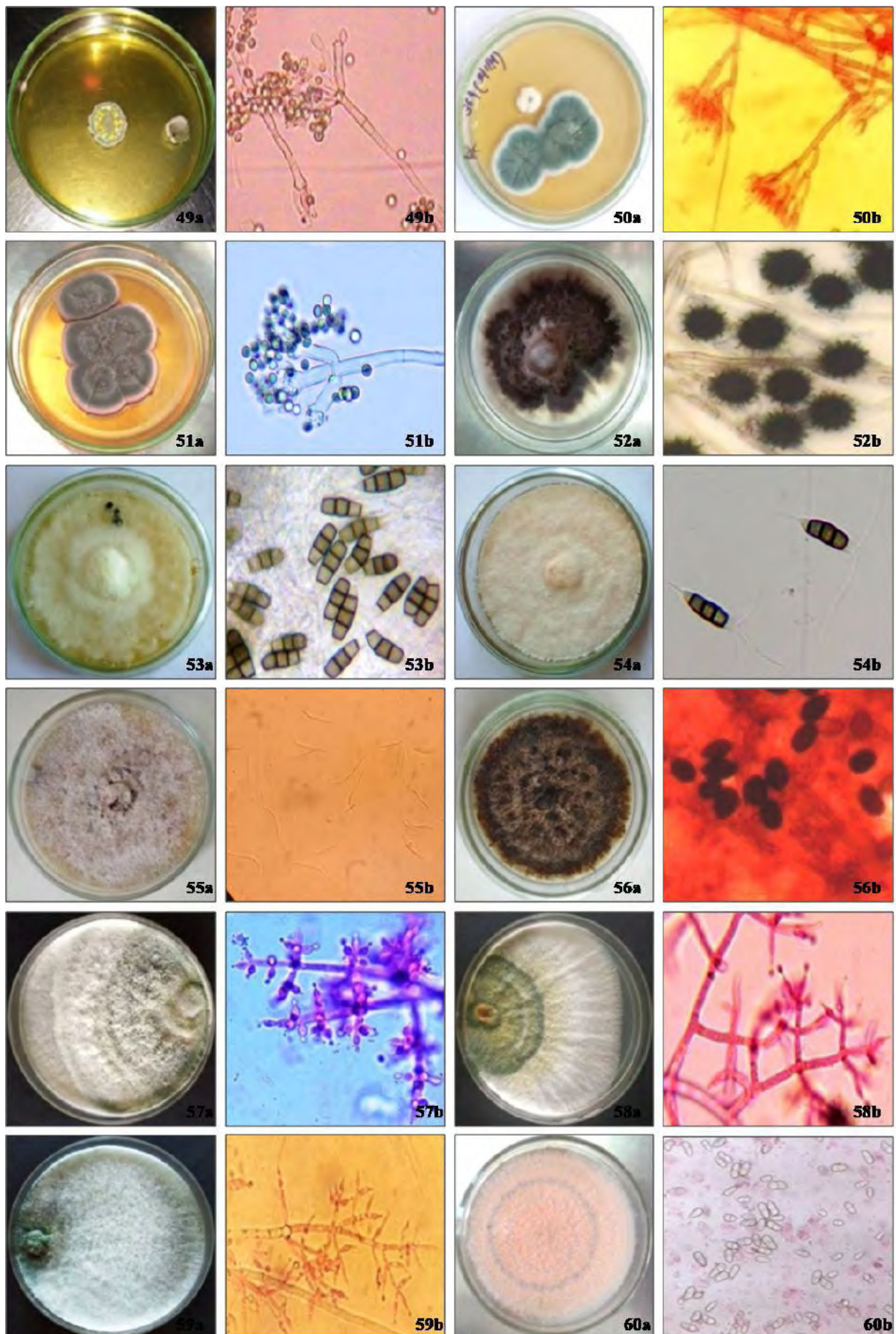




Fig. 3. Morphological and microscopic view of fungal species

lium chrysogenum, *Penicillium digitatum*, *Penicillium notatum*, *Periconia cookei*, *Trichoderma harzianum*, *Trichoderma koningii* and *Trichoderma viride*. All the fungal species reported were pathogenic in nature causing different diseases on the leaves, culms, sheaths and rhizomes of *Dendrocalamus strictus* and their disease intensity was also calculated, except for the ones which were found on the decayed culms. *Crepidotus* sp., *Hygrocybe miniata*, *Leucoagaricus* sp. and *Marasmius hematocephalus* recorded on the decayed culms were saprophytic in nature.

Disease Incidence of leaf rust by *D. divina* was recorded the highest 65.01% and 68.90% in 2015 and 2016 respectively during the study. Leaf rust was widespread in bamboo nurseries and natural stands. The infection lays great impact on leaf photosynthesis which in turn results in low stand productivity affecting growth and vigour of the infected clumps. Another major and serious disease is rot of emerging and growing culms. There are more chances of occurrence of rotten culms in unmanaged natural stands than artificial plantations. The disease lowers the quality as well as quantity of the culms produced thus lowering the productivity of bamboos. Maximum number of fungal species was recorded causing culm stain which is the result of high humidity and lack of sunshine in the area. Discoloration of culms starts with the disease resulting in infection of soft internal tissues and reduced culm productivity. Foliar diseases are equally important as they cause necrosis which results in reduced photosynthesis and subsequent leaf fall.

Fungal isolates and the diseases caused by them are listed in Table 1. The culture and microscopic pictures of fungal isolates (Fig.3.) are arranged in order of the Table 1. (for eg. 1a and 1b are culture and microscopic images of *Acremonium* sp. as listed #1 in Table 1).

Conclusion

Ascomycota or the sac fungi is the largest phyla in the fungi kingdom containing highest number of species which are both parasitic and saprobic in nature. Larger number of bambusicolous fungi falls under Ascomycota phylum which proves their great affinity for the bamboos. The occur-

rence of the diverse mycoflora in the bamboo nurseries, plantations, natural stands and stored culms is mainly due to lack of maintenance, excessive humidity, lack of sunshine, poor drainage conditions and closeness between the clumps. Proper maintenance of the stands, nurseries and timber depots is necessary for the avoidance of microorganisms, soil treatment before planting, fungicidal treatment at regular intervals, removal of litter and debris from the ground, regular pruning of the shoots and branches, adequate use of tools and implements, burning of infected culms and rhizomes etc. are some recommendations.

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