STUDY OF SOIL FUNGI FROM SELECTED SACRED GROVES OF KERALA

Thesis submitted to the University of Calicut
in partial fulfilment of the requirements
for the award of the Degree of

DOCTOR OF PHILOSOPHY

In

BOTANY

under the faculty of Science
by

KEERTHANA NANDAKUMAR

Under the guidance of
Dr. Ignatius Antony

Co-guidance of
Dr. Anto P. V

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I hereby declare that the work presented in the thesis entitled **"STUDY OF SOIL FUNGI FROM SELECTED SACRED GROVES OF KERALA"** is based on the original work done by me under the guidance of Dr. Ignatius Antony, Principal and Associate Professor (Retd.), Department of Botany, St. Thomas College (Autonomous), Thrissur and the co-guidance of Dr. Anto P. V, Associate Professor, Department of Botany, St. Thomas College (Autonomous), Thrissur and has not been included in any other thesis submitted previously for the award of any degree. The contents of the thesis have undergone a plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI-generated content.

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Keerthana Nandakumar

To my family…

ABSTRACT

Sacred groves are believed to be dense patches of the once-vast evergreen forests of southwestern India, particularly in Kerala. Soil fungi have an important role in sustaining these sacred groves' rich and diverse vegetation. However, until recently, little was known about the fungi associated with these areas. Therefore, this study investigates the diversity, composition, and abundance of soil fungi of three sacred groves located in different parts of Kerala: Iringole Kavu, Kollakal Thapovanam, and Poyilkavu. Soil samples were collected from these groves across three seasons over two years using a composite soil sampling method. The serial dilution technique and metagenomics analysis were employed to isolate and identify the soil fungi. Using the serial dilution method, a total of 34 genera and 168 species of fungi were identified across six classes, with Ascomycota being the most dominant phylum, followed by Mucoromycota. Four unidentified species and two non-sporulating fungi were also collected. Sixteen new reports for India and eighteen new reports for Kerala were documented as part of the work.

The class-wise distribution of fungi revealed that Eurotiomycetes was the most dominant class, while the genus *Penicillium*, followed by *Aspergillus*, became the predominant genus. Spatial and seasonal distribution of the taxa was analysed. Iringole Kavu exhibited the highest species richness (105 species), followed by Poyilkavu (67) and Kollakal Thapovanam (64). Seasonally, high species diversity was observed in Iringole Kavu during Pre 2, and in Mo 2 of both Kollakal Thapovanam and Poyilkavu. Fungal genera exclusive to each site and abundant species were listed. Spatial and seasonal variations in the number of fungi were documented. In the spatial and seasonal diversity analysis, Iringole Kavu exhibits a high level of diversity and maintains a balanced ecosystem. Species diversity also changes with the seasons. Hierarchical Cluster Analysis and Non-metric Multidimensional Scaling revealed that each sacred grove was distinct and possessed unique fungal flora. In total, 12 physicochemical parameters were studied, and statistical measures were calculated. The variation in these parameters across seasons was tested for significance, revealing strong influences on species diversity and distribution. Canonical Correspondence Analysis interpreted the correlations between physicochemical parameters and fungi. Indicator Species Analysis identified genera that serve as indicators for each season and site. Metagenomics analysis revealed five phyla, subdivided into 20 classes, 40 orders, 83 families, 119 genera, and 135 species. Eurotiomycetes predominated at the class level, while the genus *Talaromyces* dominated among the genera. Diversity analysis indicated that Kollakal Thapovanam was rich in fungal species. These findings highlight the unique and diverse ecosystems present in sacred groves, underscoring the need for conservation efforts to maintain their purity. This study is significant as it represents the first comprehensive analysis of soil fungi in the sacred groves of Kerala.

Keywords: Sacred groves, Soil Fungi, Diversity, Metagenomics, Kerala

സംഗ്രഹം

തെക്കുപടിഞ്ഞാറൻ ഇന്ത്യയിലെ, പ്രത്യേകിച്ച് കേരളത്തിലെ, ഒരുകാലത്ത് വിശാലമായ നിത്യഹരിതവനങ്ങളുടെ ഇടതൂർന്ന ഭാഗങ്ങളാണ് പുണ്യവനങ്ങൾ എന്ന് വിശ്വസിക്കപ്പെടുന്നു. ഈ പുണ്യവനങ്ങളുടെ സമ്പന്നവും വൈവിധ്യപൂർണ്ണവുമായ സസ്യജാലങ്ങളെ നിലനിർത്തുന്നതിൽ മണ്ണ് ഫംഗസുകൾക്ക് ഒരു പ്രധാന പങ്കുണ്ട്. എന്നിരുന്നാലും, അടുത്തകാലംവരെ, ഈ പ്രദേശങ്ങളുമായി ബന്ധപ്പെട്ട ഫംഗസുകളെക്കുറിച്ച് വളരെക്കുറച്ചേ അറിയൂ. അതിനാൽ, ഈ പഠനം കേരളത്തിന്റെ വിവിധ ഭാഗങ്ങളിൽ സ്ഥിതിചെയ്യുന്ന മൂന്ന് പുണ്യവനങ്ങളുടെ മണ്ണ് ഫംഗസുകളുടെ വൈവിധ്യം, ഘടന, സമൃദ്ധി എന്നിവ അന്വേഷിക്കുന്നു: ഇരിങ്ങോൾകാവ്, കൊല്ലക്കൽ തപോവനം, പൊയിൽക്കാവ്. രണ്ട് വർഷത്തിനിടെ മൂന്ന് സീസണുകളിലായി ഈ തോട്ടങ്ങളിൽ നിന്ന് മണ്ണ് സാമ്പിളുകൾ ഒരു സംയോജിത മണ്ണ് സാമ്പിൾരീതി ഉപയോഗിച്ച് ശേഖരിച്ചു. മണ്ണ് ഫംഗസുകളെ വേർതിരിച്ച് തിരിച്ചറിയാൻ സീരിയൽ ഡൈല്യൂഷൻ ടെക്നിക്കും മെറ്റാജെനോമിക്സ് വിശകലനവും ഉപയോഗിച്ചു. സീരിയൽ ഡൈല്യൂഷൻ രീതി ഉപയോഗിച്ച്, ആറ് ക്ലാസുകളിലായി ആകെ 34 ജനുസ്സുകളും 168 ഇനം ഫംഗസുകളും തിരിച്ചറിഞ്ഞു, അസ്കോമൈക്കോട്ടയാണ് ഏറ്റവും പ്രബലമായ ഫൈലം. തുടർന്ന് മ്യൂക്കോറോമൈക്കോട്ട. നാല് തിരിച്ചറിയാത്ത ഇനങ്ങളും രണ്ട് നോൺ-സ്പോറുലേറ്റിംഗ് ഫംഗസുകളും ശേഖരിച്ചു. ഇന്ത്യയ്ക്കായി പതിനാറ് പുതിയ റിപ്പോർട്ടുകളും കേരളത്തിനായി പതിനെട്ട് പുതിയ റിപ്പോർട്ടുകളും പ്രവർത്തനത്തിന്റെ ഭാഗമായി രേഖപ്പെടുത്തി.

ക്ലാസ് തിരിച്ചുള്ള ഫംഗസ് വിതരണം, യൂറോഷിയോമൈസെറ്റസ് ആണ് ഏറ്റവും പ്രബലമായ വിഭാഗം എന്ന് വെളിപ്പെടുത്തി, അതേസമയം പെൻസിലിയം ജനുസ്സും തുടർന്ന് ആസ്പർജില്ലസ് ജനുസ്സും പ്രബലമായ ജനുസ്സുകളായി മാറി. ടാക്സയുടെ സൈറ്റ് തിരിച്ചുള്ളതും സീസണൽ തിരിച്ചുള്ളതുമായ വിതരണം വിശകലനം ചെയ്തു. ഇരിങ്ങോൾകാവ് ഏറ്റവും ഉയർന്ന സ്പീഷീസ് സമ്പന്നത (105 സ്പീഷീസ്) പ്രദർശിപ്പിച്ചു. തുടർന്ന് പൊയിൽക്കാവ് (67), കൊല്ലക്കൽ തപോവനം (64). സീസണനുസരിച്ച്, പ്രീ 2 കാലയളവിൽ ഇരിങ്ങോൾകാവിലും, കൊല്ലക്കൽ തപോവനം, പൊയിൽക്കാവ് എന്നിവയുടെ എംഒ 2ലും ഉയർന്ന സ്പീഷീസ് വൈവിധ്യം നിരീക്ഷിക്കപ്പെട്ടു. ഓരോ സൈറ്റിനും മാത്രമുള്ള ഫംഗസ് ജനുസ്സുകളും സമൃദ്ധമായ ഇനങ്ങളും പട്ടികപ്പെടുത്തിയിട്ടുണ്ട്. ഫംഗസുകളുടെ എണ്ണത്തിൽ സ്ഥലപരവും കാലാനുസൃതവുമായ വ്യതിയാനങ്ങൾ രേഖപ്പെടുത്തിയിട്ടുണ്ട്. സ്ഥലപരവും കാലാനുസൃതവുമായ വൈവിധ്യവിശകലനത്തിൽ, ഇരിങ്ങോൾകാവ് ഉയർന്ന തലത്തിലുള്ള വൈവിധ്യം പ്രകടിപ്പിക്കുകയും സന്തുലിതമായ ഒരു ആവാസവ്യവസ്ഥ നിലനിർത്തുകയും ചെയ്യുന്നു. ഋതുക്കൾക്കനുസരിച്ച് സ്പീഷീസ് വൈവിധ്യവും മാറുന്നു. ഹൈറാർക്കിക്കൽ ക്ലസ്റ്റർ വിശകലനവും നോൺ-മെട്രിക് മൾട്ടിഡൈമൻഷണൽ സ്കെയിലിംഗും ഓരോ പുണ്യഗ്രൂപ്പും വ്യത്യസ്തമാണെന്നും അതുല്യമായ ഫംഗസ് സസ്യജാലങ്ങൾ ഉണ്ടെന്നും വെളിപ്പെടുത്തി. മൊത്തത്തിൽ, 12 ഭൗതിക-രാസപാരാമീറ്ററുകൾ പഠിക്കുകയും സ്ഥിതിവിവരക്കണക്കുകൾ കണക്കാക്കുകയും ചെയ്തു. സീസണുകളിലുടനീളമുള്ള ഈ പാരാമീറ്ററുകളിലെ വ്യത്യാസം പ്രാധാന്യത്തിനായി പരീക്ഷിച്ചു. ഇത് സ്പീഷിസ് വൈവിധ്യത്തിലും വിതരണത്തിലും ശക്തമായ സ്വാധീനം ചെലുത്തുന്നു. കാനോനിക്കൽ കറസ്പോണ്ടൻസ് വിശകലനം ഫിസിക്കോകെമിക്കൽ പാരാമീറ്ററുകളും ഫംഗസും തമ്മിലുള്ള പരസ്പരബന്ധത്തെ വ്യാഖ്യാനിച്ചു. ഓരോ സീസണിനും സൈറ്റിനും സൂചകങ്ങളായി വർത്തിക്കുന്ന ജനുസ്സുകളെ ഇൻഡിക്കേറ്റർ സ്പീഷീസ് അനാലിസിസ് തിരിച്ചറിഞ്ഞു.

മെറ്റാജെനോമിക്സ് വിശകലനം അഞ്ച് ഫൈലകളെ വെളിപ്പെടുത്തി, 20 ക്ലാസുകൾ, 40 ഓർഡറുകൾ, 83 കുടുംബങ്ങൾ, 119 ജനുസ്സുകൾ, 135 സ്പീഷീസുകൾ എന്നിങ്ങനെ വിഭജിച്ചിരിക്കുന്നു. ക്ലാസ്തലത്തിൽ യൂറോഷിയോമൈസെറ്റുകൾ പ്രബലമായിരുന്നു, അതേസമയം ജനുസ്സുകളിൽ ടാലറോമൈസിസ് ജനുസ്സാണ് ആധിപത്യം പുലർത്തിയത്. കൊല്ലക്കൽ തപോവനം ഫംഗസ്സ് സ്പീഷീസുകളാൽ സമ്പന്നമാണെന്ന വൈവിധ്യവിശകലനം സൂചിപ്പിക്കുന്നു. പുണ്യകാവുകളിൽ നിലവിലുള്ള അതുല്യവും വൈവിധ്യപൂർണ്ണവുമായ ആവാസവ്യവസ്ഥകളെ ഈ കണ്ടെത്തലുകൾ എടുത്തുകാണിക്കുന്നതോടൊപ്പം, അവയുടെ പരിശുദ്ധി നിലനിർത്തുന്നതിനുള്ള സംരക്ഷണശ്രമങ്ങളുടെ ആവശ്യകത അടിവരയിടുന്നു. കേരളത്തിലെ പുണ്യകാവുകളിലെ മണ്ണ് ഫംഗസുകളുടെ ആദ്യത്തെ സമഗ്രവിശകലനത്തെ പ്രതിനിധീകരിക്കുന്നതിനാൽ ഈ പഠനം പ്രധാനമാണ്.

കീവേഡുകൾ: പുണ്യവനങ്ങൾ, മണ്ണിന്റെ കുമിൾ, വൈവിധ്യം, മെറ്റജെനോമിക്സ്, കേരളം

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ABBREVIATIONS

μL	Microliter
μg	Microgram
μm	Micrometre
mL	Millilitre
mg	Milligram
mm	Millimetre
g	Gram
l	Litre
cm	Centimetre
m	Meter
km	Kilometre
ha	Hectare
%	Percentage
~	Approximately
var.	Variety
sp.	Species
f.	Forma
≥	Greater-than or Equal to
≤	Less-than or Equal to
<	Less-Than
>	Greater-Than
E	East
W	West
N	North
S	South
et al.,	And others
° C	Degree Celsius
dS/m	deciSiemens per meter
kg/ha	Kilograms per hectare
Cmol/kg	Centimoles per kilogram
pF	Potential force
bp	Base pair
CFU	Colony Forming Unit
OTU	Operational Taxonomic Unit
PDA, P	Potato Dextrose Agar
CDA, C	Czapek Dox Agar
NSF	Non Sporulating Fungi
ITS	Internal Transcribed Spacer
PCR	Polymerase Chain Reaction

DNA	Deoxyribonucleic acid
VAM	Vesicular arbuscular mycorrhiza
Temp	Temperature
OC	Organic Carbon
MC	Moisture Content
EC	Electrical Conductivity
WHC	Water Holding Capacity
Avail. N	Available Nitrogen
Avail. P	Available Phosphorus
Avail. K	Available Potassium
Ex. Ca	Exchangeable Calcium
Ex. Na	Exchangeable Sodium
L.	Linnaeus
Viz	Videlicet
&	And
AD	Anno Domini
HCA	Hierarchical Cluster Analysis
NMDS	Non-metric Multidimensional Scaling
CCA	Canonical Correspondence Analysis
ANOVA	Analysis of Variance
PAST	Paleontological Statistics
MDS	Multidimensional Scaling
PCoA	Principle Coordinate Analysis
SRA	Sequence Read Archive
NCBI	National Centre for Biotechnology Information
MIMS	Minimal information about metagenomics sequence
KSCSTE	Kerala State Council for Science, Technology and Environment
IUCN	International Union for Conservation of Nature
SNS	Sacred Natural Sites
ISG, S1	Iringole kavu
KSG, S2	Kollakal Thapovanam
PSG, S3	Poyilkavu
Pre 1	Pre-Monsoon 1
Mo 1	Monsoon 1
Po 1	Post-Monsoon 1
Pre 2	Pre-Monsoon 2
Mo 2	Monsoon 2
Po 2	Post-Monsoon 2

Chapter 1

Introduction

1.1 General Introduction

Sacred groves, a strategy developed by humans, have endured in the world for ages as one of the finest instances of traditional conservation methods. They are the areas of dense vegetation that preserve nature's unique biodiversity and are safeguarded by the local community due to their cultural and religious beliefs and taboos. According to Hughes and Chandran (1998), sacred groves are the *"areas of land that include vegetation, various life forms, and geographical characteristics, set apart and safeguarded by human communities due to their belief that maintaining these areas in a pristine condition symbolises a significant connection between humans, the divine, and the natural world".*

Virgin forests were thought to be pre-Vedic in origin. Gadgil and Vartak (1975) tracked their archival link to societies' pre-agricultural, hunting and gathering stages. Every sacred grove was associated with its own myths, stories, and traditions and has been significant in the ancient mythologies and cultural customs of Scandinavian, Greek, Slavic, and Roman societies, as well as those in old Europe, Asia, and Africa, especially in India, Japan, West Africa, Anatolia, and China (Bhagwat and Rutte, 2006; Ormsby, 2012; Malhotra, 1998). Their presence has also been noted in countries like Ghana, Syria, Nigeria, Turkey, Bangladesh, Nepal, Senegal, and Sumatra (Gadgil and Vartak, 1976; Hussain, 1998). Nonetheless, these groves were destroyed in Europe, West Asia, and many other regions due to the emergence of modern religions and the resulting shifts in humanity's perspective towards nature (Hughes and Chandran, 1998).

The International Union for the Conservation of Nature and Natural Resources (IUCN) considered sacred groves as "Sacred Natural Sites" (SNS) - "natural areas of special spiritual significance to peoples and communities" (Oviedo et al., 2005). SNS became the most widely used term, even though Indigenous people use a variety of terms such as sacred groves (Bhagwat and Rutte, 2006), sacred forests (Daniel et al., 2016), sacred landscapes (Babalola et al., 2014), or dreaded forests (Jimoh et al., 2012). The size of sacred groves can vary significantly, ranging from a few trees to expansive areas covering hundreds of acres. The largest known sacred grove is Halesorabakan, which spans approximately 400 hectares (Brandis and

Grant, 1868). Some sacred groves are located as isolated islands in open plains or deserts, while others are part of larger forested areas. According to Ormsby (2012), India holds some of the highest numbers and densities of sacred groves in the world.

India, a land of diverse natural resources, has a long-established tradition of preserving nature, keeping it intact due to religious beliefs, and infusing it with a cultural essence that dates back to the pre-Vedic era. The earliest document addressing the sacred groves of India, written by Brandis (1897), notes that "*very little has been published about sacred groves in India, yet they were, and still are, quite numerous. Typically, these groves remain untouched by the axe, except when wood is needed for the repair of religious buildings*." These sacred groves represent our biological heritage and serve as true indicators of the climax vegetation that existed before the rise of modern civilisation. Their diverse plant life and potential for conservation are significant enough to be acknowledged as "mini biosphere reserves" (Gadgil and Vartak, 1975). According to India's National Environment Policy, ancient sacred groves should be regarded as possessing "Incomparable Values" (Government of India, 2006).

In India, sacred groves have been reported from Khasi Hills in Meghalaya in the northeast, Aravalli ranges of Rajasthan in the northwest, all along Western Ghats in the southern peninsula and Madhya Pradesh in central India, i.e. from scrub forests in the Thar Desert of Rajasthan to the tropical rain forest of Kerala in Western Ghats (Gadgil and Vartak, 1976; Burman, 1992; Rodgers, 1994; Balasubramanyam and Induchoodan, 1996; Tripathi, 2001; Khumbongmayum et al., 2005; Mitra and Pal, 1994). They are commonly linked with Hindu deities, although there are also sacred groves with Islamic and Buddhist origins and were known by different names in different parts of the Country (Khan et al., 2008), for example, Pavithra-vanalu (Andhra Pradesh), Ranthii (Arunachal Pradesh), Dev (Madhya Pradesh), Devrai (Maharashtra), Sarnas (Bihar), Orans (Rajasthan), Nagabana (Karnataka), Kovilkadu (Tamil Nadu), Kavu (Kerala), Dev van (Himachal Pradesh), Ki Law Kyntang (Meghalaya), Jaherthan (Jharkhand), Lai Umang (Manipur), Garamthan (West Bengal), etc. (Malhotra et al., 2001; Khumbongmayum et al., 2004; Khan et al., 2008; Ormsby and Bhagwat, 2010; Parmar and Patel, 2010; Basha et al., 2012; Krishna and Amirthalingam, 2014; Lalitha, 2015; Manoharan and Chinnappan, 2019).

According to Gokhale et al. (1998), it has been estimated that the overall area of sacred groves in India was 33,000 hectares, which represents 0.01 per cent of the nation's total land area. However, the actual area may be as much as 42,000 hectares, given the 4,415 sacred groves that have been documented thus far (Gokhale et al., 1998). Nevertheless, preliminary research suggests that the total number of sacred groves across the country could be anywhere between 100,000 and 150,000, spread across 19 of the 28 states in India (Malhotra, 1998). In contrast, the C.P.R. Environmental Education Centre has verified a total of 10,377 sacred groves. The largest concentration of sacred groves, numbering 5,000, has been found in Himachal Pradesh, followed by Kerala.

In Kerala, sacred groves, known as Kavu in Malayalam, are thought to be remnants of the extensive evergreen forests that once existed in southwest India. These groves are often located near temples or ancient Tharavadus (houses) and can be found all across the state. The first documented account of sacred groves was included in the Census report of Travancore, where Lieutenant Ward and Lieutenant Corner (1827) noted the existence of 15,000 sacred groves that span 500 hectares of forested land (Prasad and Mohanan, 1995), which constitutes 0.05% of the state's entire forest area (Chandrashekara and Sankar, 1998a). Their distribution does not coincide with forested regions and was primarily situated in the lowland areas of Kerala.

Sacred groves in Kerala are mainly devoted to serpent deities (*Sarpakkavu* in the south and *Nagam* in the north), Goddess Bhagavathy (*Bhagavathykkavu*) or Lord Ayyappa (*Ayyappankavu or Sasthamkavu*) (Chandran and Gadgil, 1993a). Some groves are dedicated to spirits, demons or ancestors (*Yakshikkavu, Madankavu* and *Appoppankavu*). In North Kerala, there are groves dedicated to male gods (*Daivakkavu),* and Kottam and Mundya are groves exclusively dedicated to Vettakkorumakan and Gulikan, respectively. These sacred groves are mostly owned and managed by ancestral families. The rest of the groves are managed by the Devaswom Board of the Government of Kerala, State Forest departments, or the temple trusts.

These sacred groves are protected through 'social fencing' (Khumbongmayum et al., 2005) since the local communities consider them as the abode of Gods or Goddesses or their ancestral spirits. They believed that harming any animal or cutting off trees in sacred groves leads to the deity's wrath (Gadgil and Vartak, 1974; Dagla et al., 2007; Samati and Gogoi, 2007). Thus, the entire flora and fauna are safeguarded, and it was forbidden to remove any vegetation, including deadwood. Research has shown that well-maintained sacred groves are on par with local natural forests in terms of various ecological factors (Gadgil, 1985; Chandran et al., 1998; Hughes and Chandran, 1997, 1998; Godbole et al., 1998; Anupama, 2009; Tiwari et al., 1998; Malhotra et al., 2001; Nair et al., 2013).

The extensive floristic diversity studies of sacred groves in the Western Ghats and Kerala over the last thirty years revealed that these undisturbed groves serve as vital reservoirs of flora and fauna, including numerous rare, endangered, and endemic species. Even the smallest groves harbour remarkable old trees and climbing plants. Also, they house a variety of genetic pools, wild relatives of many crop species and a wide array of medicinal plants that are often absent from surrounding forests (Induchoodan, 1998, 1992, 1996; Chandrashekara and Sankar, 1998a, 1998b; Chandran and Gadgil, 1993a, 1993b; Chandran et al., 1998; Sreeja and Unni, 2010; Sreeja, 2008, 2013; Ramachandran and Mohanan, 1991; Rajendraprasad, 1995; Joshi and Gadgil, 1991).

Moreover, the time-honoured tradition of having a temple, a tank, and a connected sacred grove illustrates the ancient practices of water collection and distribution in the villages of Kerala. Sacred groves, such as the one in the Kannur district that gives birth to the Kavvai River (Mohanan and Prasad, 2004), are crucial sources of water for the plants and animals that inhabit them (Puspangadan et al., 1998). These water resources also play a significant role in reducing temperature and creating a favourable microclimate for various organisms (Khiewtam and Ramakrishnan, 1989). Additionally, sacred groves help in preventing forest fires, aiding in nutrient cycling, and conserving soil by retaining water and binding soil. Overall, these groves offer crucial ecological services to humanity. All these factors highlight the importance of protecting these sacred sites.

Although sacred groves may not be as prominent as they once were, they still hold significance in the rural landscapes of India where traditional communities reside. Recently, there has been an increase in interest in this tradition, leading to scientific studies. However, major studies were conducted on plant and animal species diversity in sacred groves, and not much attention has been given to the microbiota of the soil, especially soil fungi as they were the crucial components of the natural forest ecosystem (Hackl et al., 2004).

Fungi are unique, ubiquitous organisms representing one of the six kingdoms of life (Tang et al., 2006; Read and Boddy, 2010). They constitute the second largest group on Earth after insects (Hawksworth, 1991), encompassing a wide variety of forms, including morels, molds, truffles, mushrooms, yeasts, rusts, smuts, puffballs, and many lesser-known organisms (Alexopoulos et al., 1996). They are eukaryotic, unicellular or multicellular, heterotrophic organisms (Palm and Chapela, 1997; Crespo et al., 2014) playing a significant role in the sustainability of the biosphere.

Fungi consist of microscopic cells that generally form lengthy threads or strands called hyphae, which can sometimes accumulate into masses known as mycelium. These hyphae extend by forcing their way between particles of soil, roots, and rocks, typically measuring just a few micrometres in diameter. Fungal fruiting bodies are made up of hyphal strands and spores. They inhabit various organic materials like decaying wood, plant debris, soil, submerged plant remains, driftwood, insects, nematodes, and herbivore dung (Dix and Webster, 1995), and depending on their relationships, they are categorised as endophytes, saprophytes, mutualists, or parasites. Numerous classification systems for fungi have been suggested for the convenience of researchers, yet the most accepted classification was that proposed by Ainsworth et al. (1973). This classification aligns with the guidelines of the International Code of Botanical Nomenclature, treating fungi as a separate kingdom divided into two groups: Myxomycota and Eumycota for plasmodial and non-plasmodial types, respectively, which are further divided into 22 phyla.

Fungi are crucial for maintaining ecological balance, as emphasised by Stamets (2005). Soil microbial processes, particularly the mineralisation of organic nutrients, greatly influence the overall primary production of natural ecosystems by providing the necessary nutrients for plant growth (Paul and Clark, 1997) and microfungi make up a great deal of microbial activity in the soil. Fungi form a vital part of the soil microbiota and typically make up a larger portion of soil biomass than bacteria, depending on factors like soil depth and nutrient availability (Ainsworth and

Bisby, 1995). Satchell (1971) stated that "the fungi emerge as outstandingly the most important decomposer organisms" and thus facilitate the biogeochemical cycles in the ecosystem. Fungi have long been used as food in the form of edible mushrooms and are widely applied in the fermentation of diverse food products such as bread, wine and beer (Bennett, 1998). Additionally, they offer valuable pharmaceutical products to humanity, such as antibiotics and other important substances like organic acids, enzymes, pigments, and secondary metabolites (Pointing and Hyde, 2001). Furthermore, numerous soil fungi contribute to water filtration, soil water retention, soil structure (Wright and Upadhyaya, 1998; Dodd et al., 2000), soil fertility (Yao et al., 2000; Daniell et al., 2001), act as biological control agents against plant pathogens and insect pests, and assist in biodegrading waste (Stamets, 2005; Lange 2010, 2014; Lange et al., 2012). Some also serve as model organisms in various scientific studies (Davis, 2003; Van Der Klei and Veenhuis, 2006; Ohm et al., 2010). Hence, the connection between the diversity of soil fungi and ecosystem functionality is an issue of great significance, especially in light of global climate change and human-induced alterations to ecosystem processes.

Despite their significance, fungal diversity largely remains unexplored. Hawksworth (1991) estimated the fungal diversity to be 1.5 million species of fungi, which was about six times more than the estimated number of vascular plant species. However, recent studies estimated the presence of 5 million fungal species exist on Earth's surface (Blackwell, 2011). In contrast to this huge, estimated number, according to the 10th edition of the Dictionary of the Fungi (Kirk et al., 2008), only 98,128 fungal species have been recorded. Regardless of the difference of opinion, it was apparent that our knowledge about actual diversity lags (Arnold et al., 2000). Even though, it is expected that the fungal diversity in tropical areas is much greater than in other regions, due to microhabitats, warm temperatures, high humidity, diverse vascular plants, dependent herbivore species, and rich ecological niches, these areas have yet to be fully explored for fungi due to their vastness, lack of experts in the subject, and limited resources (Subramanian, 1982; Hawksworth and Rossman, 1997; Hawksworth, 2004; Aime and Brearley, 2012). In the words of Hawksworth (1991), *"The world's undescribed fungi can be viewed as a massive potential resource which awaits realisation"*. India is such a country in the tropics which features two mega-biodiversity zones, namely the Western Ghats and Eastern Himalayas, both recognised for their rich fungal diversity (Bhat, 2000; Bhat et al., 2009). Studies emphasise that about one-third of the world's mycobiota has been documented from India (Goswami and Ojha, 2004; Sarbhoy et al., 1996). Evidence provided by Subramanian (1986) highlights the significant number of new fungal species yet to be discovered in India.

Moreover, the distribution, generic composition, and quantity of mycoflora are influenced by the organic content of the soil and various soil and climatic conditions, surface vegetation, and soil texture. Ling-Young (1930) emphasised that to gain a comprehensive understanding of endemic mycoflora, soils from locations like forests, peat bogs, and mountains that remain undisturbed by human activity should be examined. However, studies on fungal distribution in soil have primarily concentrated on agricultural, desert, and saline soils, leaving a knowledge gap concerning fungal presence in natural soil conditions (Van Maanen et al., 2000; Gourbiere et al., 2001; Cabello and Arambarri, 2002; Schmit and Mueller, 2007; Banakar et al., 2012). In India, research on soil fungal diversity concerning habitat, climate, and altitude has been quite limited (Satish et al., 2007), especially in Kerala.

As a result, there is a lack of accurate data on the soil fungi in the natural forests of Kerala. There has been minimal research on the taxonomy, distribution, species diversity, composition, and seasonal and spatial variations of soil fungi in sacred groves in Kerala, which is why this current study is being conducted. Additionally, the relationship between soil physicochemical parameters and fungal community development was examined. Through this research, we aim to enhance our comprehension of soil microbial dynamics in natural ecosystem succession and offer valuable insights into the mycobiota present in Kerala's sacred groves.

1.2 Objectives of the Study

1. To isolate the soil fungi and to study the taxonomy of soil fungi from selected sacred groves in Kerala.
2. To compare the seasonal and spatial distribution of soil fungi from the study area.
3. To quantify and compare the diversity of soil fungi using diversity indices.
4. To derive the relation between the physicochemical aspects of soil with soil

fungi.

5. To study the total soil fungi from the study area using the Metagenomics analysis.

1.3 Area of the Present Study

In the present study, we selected three sacred groves from three different parts of Kerala. The selection was purely based on the area of the sacred grove and permission to enter the sacred grove. We selected Iringole Kavu (ISG) (S1) (10°06′32.71″ N and 76°30′01.44″ E) from the Central part of Kerala, Kollakal Thapovanam (KSG) (S2) (9°11′05.19″ N and 76°27′41.30″ E) from the Southern part of Kerala and Poyilkavu (PSG) (S3) (11°24′31.49″ N and 75°42′49.37″ E) from the Northern part of Kerala.

1.3.1 Iringole Kavu

Iringole Kavu is one of the largest natural sacred groves in Kerala (https://forest.kerala.gov.in/index.php/flora), with a total area of about 20.234 hectares. It is in the Perumbavoor of Ernakulam District, Kerala, with a hot and humid climate. In the central part of the grove is the ruling deity, Iringole Kavil Amma, who is considered *Vana Durga*. This sacred grove is linked to a fascinating myth involving three goddesses who roamed the world and established themselves in three different places, one being Iringole. The term ‘Iringole’ is derived from ‘Irunna Aval,’ meaning ‘she who rested here.’ Locals believe that the three goddesses still convene in the grove during the evenings and spend the night there, which is why no one is permitted to remain in the grove after dark. The vegetation type of the grove was reported as West Coast Tropical Evergreen type (Shanthakumar et al., 2010). This sacred grove has a very rich flora and fauna, including valuable herbs, medicinal plants, monkeys, squirrels and mynah, with around 185 angiosperm species documented here (Chandrashekara, 2011). Iringole Kavu is associated with two freshwater ponds. The grove was once owned by the 28 families and now the ownership was transferred to the Travancore Devaswom Board, Government of Kerala. In Iringole Kavu, every plant is deemed divine and is therefore protected from being cut down.

1.3.2 Kollakal Thapovanam

Kollakal Thapovanam is a man-made sacred grove located in Harippad of Alappuzha district, Kerala, with a total area of 1.214 hectares. The sacred grove is owned by Devaki Amma of Kollakal House, and she planted as many trees as she could and made the grove a larger one. Devaki Amma was honoured with the most prestigious award, "The Nari Sakthi Puraskar", by the Government of India for creating and preserving this sacred grove. The ruling deity of this grove is "Kuriyala Vallichan", the ancestor of the family. It is associated with two freshwater ponds and is about 3 km away from the Sea.

1.3.3 Poyilkavu

Poyilkavu is a natural sacred grove situated in the Koyilandy of Kozhikode district, Kerala, believed to be one of 108 Durga temples established by the legendary Lord Parasurama. The total area of the grove is about 4.62 hectares with Semi-evergreen type vegetation and is just 250 m away from the Seashore. In the central part of the grove is the ruling deity, Poyilkavil Amma, who is considered *Vana Durga*. The grove is densely populated with mature evergreen tree species, lianas, and underbrush, featuring a temple structure in the center, characteristic of Kerala temples. The sacred grove is associated with a small freshwater pond, "Thirukuzhi", and squirrels, birds, snakes, foxes, and porcupines are very common in this grove. The tall trees in the grove are occupied with bats, and the grove is home to approximately 90 angiosperm species, including 14 endemic species (Chandrashekara et al., 2018). During the rainy season, several springs are seen, and the surface of the grove is filled with water. Poyilkavu is owned and managed by the Malabar Devaswom Board, Government of Kerala.

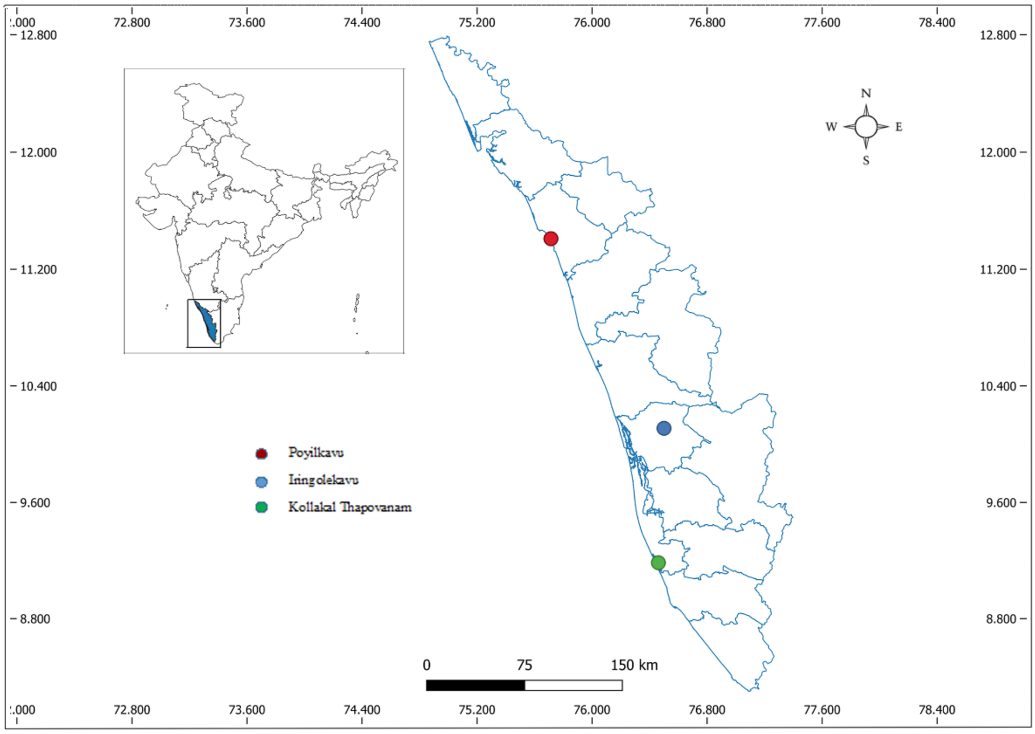

Figure 1. Map of Kerala showing selected sacred groves

Figure 2. Photos of selected sacred groves: A – Iringole Kavu, Ernakulam. B – Kollakal Thapovanam, Alappuzha. C – Poyilkavu, Kozhikode.

Chapter 2

Review of Literature

2.1 Sacred Groves

"The groves were God's first temples. Ere man learned
To hew the shaft, and lay the architrave…
In the darkling wood,
Amidst the cool and silence, he knelt down"

(Bryant, 1848)

Sacred groves are natural areas that contain trees, wildlife, and unique geological formations. These places are valued and preserved by communities because they view the maintenance of these relatively untouched spaces as a reflection of their vital connection to nature or the divine. Ecologically and culturally vital sacred groves can be found all over the world, among people of different religions, social and economic backgrounds, and historical periods, with references found in Greek and Sanskrit literature. They also became significant elements in the mythological landscapes of ancient Europe, Germanic pagan beliefs, Greek legends, Slavic mythology, Roman lore, and Druid traditions. Moreover, they have had a substantial impact on various mythologies and cultural practices in many Asian and African regions, especially in India, Japan, West Africa, and Anatolia. Although not systematically recorded, examples of these sacred sites are plentiful and can be found on every inhabited continent and many oceanic islands.

2.1.1 Distribution of Sacred Groves

2.1.1.1 World Scenario

In Africa, sacred groves are found throughout the sub-Saharan region of the continent. In Egypt, ancient temples had sacred groves and lakes within their precincts (Erman, 1894), and the Senufo religion in the Ivory Coast was centred on a sacred grove (Spindel, 1989). The Kikuyu people in East Africa consider the Mugumu tree to be sacred (Frazer, 1935), while in West Africa, the holiness of these botanically rich groves has kept them safe from being felled by lumber companies (Bachmann, 1992). The Malshegu community in Ghana has preserved a small forest (0.8 ha) that they believe houses a local spirit (Dorm-Adzobu et al., 1991), while in

Sierra Leone, sacred groves are home to medicinal plants (Lebbie and Guries, 1995).

Sacred groves were also highly revered in Europe. Dodona was the most notable sacred grove in mainland Greece, while the Academy location in Athens was a sacred area filled with olive trees (Hughes, 1983). The town of Nemi in Central Italy, known as the "Grove of Ariccia," housed one of the most renowned Roman cults and temples. The Bosco Sacro in Bomarzo, Italy, was a famous garden of sculptures and a sacred grove (Frazer, 1935). The Zyrians (Komi) had active sacred groves that were documented by the artist-ethnographer Wassily Kandinsky in 1889 (Weiss and Kandinsky, 1995).

Sacred groves were also seen in the Austro-Pacific region. The “Dreaming” grove of the Yarralin People (Molyneaux, 1995) and the grove of the Dieri tribe of Central Australia (Burman, 1992) are examples. In New Zealand, the Māori have sacred sites called Waahi Tapu, which encompass trees and forests among various other natural elements (Matunga, 1994). Before European colonisation, many indigenous people in the Americas believed that the Earth and all living things were sacred (Hughes and Swan, 1986).

In Asia, sacred groves are present in almost all regions of the continent. The literature from ancient Sumeria reveals their existence from the fourth millennium BC (Sandars, 1977). Similarly, the Roman writer Diodorus of Sicily reported a palm forest in Arabia with an ancient altar bearing an inscription in an unknown language (Oldfather, 1933). In Siberia, the Ostyaks and Voguls, nomadic people living in the Ob River basin, had sacred groves where nothing could be touched (Frazer, 1935). Korea has village groves (Kim, 1994), and Japan has Shinto shrines surrounded by trees and often by extensive thick forests with sacred trees (Ono, 1962). The Chinese monastery groves preserved Ginkgo, a curious archaic gymnosperm (Bachmann, 1992).

2.1.1.2 Indian Scenario

Sacred groves have been a part of India's landscape since ancient times. In the first documented account of sacred groves of India, Brandis D. (1884), the 1st Inspector General of Forests in India, mentioned visiting a sacred forest filled with Sal

(*Shorea robusta* C.F.Gaertn.) trees in Gorakhpur (Uttar Pradesh), which was home to a Muslim saint named Mian Sahib. In 1897, he wrote that, "*Very little has been published regarding sacred groves in India, but they are, or rather were, very numerous. I have found them in nearly all provinces… I may mention the Garo and Khasia hills, the Devara Kadus or sacred groves of Coorg, the hill ranges of the Salem district in the Madras Presidency, Swami Shola on the Yelagiris, and the sacred grove at Pudur on the Javadis, several sacred forests on the Shevaroys and numerous in Rajputana. These sacred forests, as a rule, are never touched by the axe, except when the wood is wanted for the repair of the religious buildings*" (Brandis, 1897). Frazer (1935) found that the Munda people of Bihar had a sacred grove called *Sarna* in every village, and they sought permission through sacrifice before cutting a tree.

In 1976, Gadgil and Vartak documented sacred groves from various regions in India, including the Khasi and Jaintia Hills of the Northeast, the Aravalli Hills in the South, the Sarguja, Chanda, and Bastar regions of Central India, as well as the Western Ghats in the Southern peninsula. The tribal communities of Chotanagpur in Central India typically worship in groves of Sal trees (*Shorea robusta*). Furthermore, they surveyed sacred groves in Maharashtra and highlighted their significance in conserving biodiversity.

In Rajasthan, the Bishnois protected groves that had Khejari trees (*Prosopis cineraria* (L.) Druce) as well as blackbuck (*Antlope cervicapra* L.). They planted a grove of 363 Khejari trees in honour of Amrita Devi and other Bishnois who sacrificed their life to protect these trees (Weber, 1989).

Sacred groves were recorded by Burman (1992) from all along the Himalayas, from the Northwest to the Northeast. The groves of Dudh and Dhelki Kherias of Central India are known as *Jankor* or *Sarna,* and to the Santai tribals, the groves are known as *Jaher*. Additionally, Jaintia Hills may have over 200 groves and were known as Lakyntang.

Ramakrishnan (1996) revealed that nature conservation has been a longstanding tradition in India, dating back to the pre-Vedic era. Malhotra (1998) reported sacred groves across several regions in India, which are estimated to be between 1,00,000 and 1,50,000, including the Himalayas, North-east India, highlands of Orissa, Bihar, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu and Kerala. However, detailed inventories are not available for the sacred groves in Chhattisgarh, Jharkhand, West Bengal, and Uttaranchal.

Gokhale et al. (1998) estimated that the total area occupied by sacred groves in India was around 33,000 hectares, which represents only 0.01% of the overall area of the country. Nevertheless, the actual area accounted for by the 4,415 sacred groves documented so far exceeds 42,000 hectares. The largest number of sacred groves has been identified in Himachal Pradesh, Kerala, Maharashtra, and Karnataka (Malhotra et al., 2000).

2.1.1.3 Kerala Scenario

Sacred groves played a vital role in the lives of traditional Hindu families in Kerala until the beginning of this century. They consist of groves and ponds that formed a unique ecological system and were closely linked to the people's lives and culture. Although sacred groves are spread throughout the state's lowlands, extending towards the foothills, very few are located in the high ranges of Idukki and Wayanad districts. Unfortunately, there is currently no comprehensive inventory of Kerala's sacred groves, and literature regarding their distribution was scarce.

The first credible documentation of sacred groves was included in the Census report of Travancore from 1891, authored by Lt. Ward and Lt. Conner, who reported 15,000 sacred groves in the region (Ward and Conner, 1827). In 1887, Logan referenced countless sacred groves in his significant work, the Malabar Manual. Historical accounts, legends, and folk songs provide insight into the sacred groves of ancient Kerala. The 'Thottampattu,' thought to have been composed between 500 and 600 AD, identifies 108 prominent ‘Ayyappan Kavus’ and alludes to many more distributed across Kerala (Veluppillai, 1940).

In 1991, Ramachandran and Mohanan documented 239 major sacred groves in Kerala. Unnikrishnan (1995) catalogued 62 sacred groves in Kasaragod and 57 in Kannur district. Reports by Rajendraprasad (1995) and Rajendraprasad et al. (1996) indicated that there are approximately 2000 reasonably well-preserved sacred groves in Kerala, while Balasubramanyam and Induchoodan (1996) identified 761 significant sacred groves in the state. In 2016, Notermans et al. concluded that only 2000 sacred groves exist in Kerala.

Raj and Tharakan (1983), along with Radhakrishnan (1989) noted that in Kerala, land reforms have led to the fragmentation and decrease in the size of sacred groves. Unnikrishnan (2010) reported a significant decline in the number of sacred groves, with major threats stemming from the shift from extended to nuclear family systems, changes in property ownership, and the construction of houses (KSCSTE, 2005).

2.1.2 Major Studies on Sacred Groves

2.1.2.1 Indian Scenario

Gadgil and Vartak (1974) reported that in India, sacred groves contained lush monsoon forests and were safeguarded due to religious beliefs. They deduced that sacred groves represent the pinnacle of vegetation where both flora and fauna are preserved (Gadgil and Vartak, 1975). While Gadgil and Chandran (1989) are of the view that sacred groves can form the epicentre for the recouping of degraded forest ecosystems in an area.

According to Hughes and Chandran (1998), sacred groves in India have been preserved for centuries because of cultural and religious traditions. These groves shelter rare and endangered plant species of considerable ecological and economic importance, making them an essential resource for future generations. The Khejari (*Prosopis cineraria*), a crucial species, was discovered in the Orans of Rajasthan. The Kallabbekan sacred grove in Kumta taluk, Karnataka, was abundant in endemics such as wild nutmeg, Cinnamon, *Garcinia gummi-gutta* (L.) N.Robson, and wild pepper (Chandran et al., 1998). Tiwari et al. (1998) noted that in Meghalaya, the sacred groves, once prevalent in every village as part of their cultural legacy, have now dwindled to just 79. Most of these groves were located in the Cherrapunji area of the East Khasi Hills District.

The sacred groves of India have been extensively studied from both anthropological and biological conservation perspectives (Ramakrishnan, 1996; Malhotra and Das, 1997; Malhotra, 1998; Deshmukh et al., 1998; Chandrashekara and Sankar, 1998a, 1998b; Gokhale et al., 1998; Ramakrishnan et al., 1998). Additionally, various earlier studies have concentrated on the floristic and ethnobotanical dimensions of sacred groves, offering a comprehensive scientific understanding of these distinctive ecosystems in India (Gadgil and Vartak, 1975, 1976, 1981; Malhotra and Das, 1997; Malhotra, 1998; Malhotra et al., 1997, 2000).

Ramsankar (2000) reported that sacred groves were serving as plant refuges and religious interdictions protected flora and fauna within these groves. He identified 106 species, including 55 indigenous tree species from the sacred groves in Purulia District, West Bengal, India. According to Boraiah et al. (2003), nature conservation was a tradition in India right from the pre-Vedic era, and 60% of the species growing in sacred groves have medicinal properties, and 40% of these are specific to that grove.

Sanjeeva and Upreti (2004) identified 17 species of lichens from Ugavai sacred grove in Maharashtra, India. *Tetramelas poeltii* (T. Schauer) Kalb., an endemic lichen to the Western Ghats, indicated the healthy conditions of the sacred grove.

Bhagwat et al. (2005) stated that the biodiversity within sacred groves was significantly affected by the surrounding trees, making it essential to ensure the sustainability of coffee plantations in Kodagu to protect the biodiversity of these groves by engaging local communities. Waghchaure et al. (2006) noted that sacred groves serve as mini sanctuaries for water resources and foster cultural ties while promoting social harmony, but they have been disrupted by modernisation. Therefore, the protection and enhancement of these groves should be integrated into village and forest management plans.

Sukumaran and Jeeva (2008) identified 98 species of angiosperms within the sacred forests of Agastheeshwaram, Tamil Nadu, including rare, endangered, and endemic plants unique to this grove. They mentioned that the grove's cultural and spiritual practices have played a crucial role in protecting its vegetation. Sukumaran et al. (2008) reported finding a total of 329 species of angiosperms across 251 genera in the sacred forests of Kanyakumari district. Among these, 42 species are endemic, with 40 categorised as very rare, 47 as rare, and 16 as endangered. They attributed the biodiversity richness and the presence of endangered and rare species to minimal disturbance. In 2009, they documented 24 species of pteridophytes from three sacred forests in the Kanyakumari district, with three being endemic to the southern Western Ghats, three endangered, and eight rare (Sukumaran et al., 2009). Ganesan et al. (2009) recorded 133 plant species across 113 genera from the sacred groves in and around Pallapatty village, Tamil Nadu.

Ormsby and Bhagwat (2010) reported that India was home to over 100,000 sacred forests, which serve as vital refuges for biological diversity, including medicinal plants, amid highly human-influenced environments. They recommended that continued support for the tradition of sacred forests was necessary due to the many threats they face.

Rao and Sunitha (2011) documented 69 medicinal vascular plant species utilised by Chenchu tribal communities from the Rudrakod sacred grove situated in the Nallamalai hill ranges of Southern Andhra Pradesh. The over-exploitation and improper harvesting practices are leading to the extinction of certain plants. Sambandan and Dhatchanamoorthy (2012) emphasised the urgent need for raising awareness among rural populations to restore such groves, as they recorded 59 plant species from 55 genera in the sacred grove of Karaikal district. Gnanasekaran et al. (2012) also highlighted the importance of conserving sacred groves and listed a total of 180 species and two varieties from 151 genera of angiosperms from Sendirakillai Sacred Grove, Tamil Nadu, including three endemic species and three species restricted to peninsular India and Sri Lanka.

Savithrammaa et al. (2013) identified 35 medicinal plants capable of treating 31 different ailments found in the sacred grove located in the Tirumala-Seshachalam hill range, Andhra Pradesh, India, and emphasised the importance of their preservation.

Blicharska et al. (2013) indicated that the sacred groves in the northern Western Ghats are abundant in biodiversity, act as a significant source of water and medicinal plants, offer regulating services such as pollination, and are essential ecosystems. However, the Konkan region is facing numerous challenges. He proposed that the conservation of sacred groves can only be achieved through the involvement of local communities. Vipat and Bharucha (2014) also supported the study, stating that eco-development, eco-restoration, and sustainable tourism, along with strong local participation, can help prevent the degradation of sacred groves.

Jayapal et al. (2014) documented 180 plant species belonging to 158 genera in the Muniandavar Sacred Groves of Thanjavur, Tamil Nadu, and called for measures to protect the sacred grove. In contrast, Ray et al. (2014) pointed out that the ecological roles of lower life forms and the hydrological processes, such as water yield, within sacred groves are not thoroughly understood. They stressed the necessity for additional research on fundamental ecological functions and ecosystem dynamics to improve the planning and management of sacred groves in a scientifically informed way. Kandari et al. (2014) noted that modern advancements have undermined both cultural and biological integrity, indicating that effective management and conservation are crucial for the sustainability of forests near human settlements. Gulia et al. (2015) also echoed these findings.

Chaoudhuri et al. (2017) examined the role of fungi in the sacred grove at Taminh, reporting that fungi play a significant part in nutrient cycling as they serve as the primary decomposers, and various insects rely on fungi for food and as a place to lay eggs. They also identified entomogenous fungi such as Cordyceps and Clathrus basket fungi.

2.1.2.2 Kerala Scenario

Nair and Mohanan (1981) discovered a new endemic species, *Kunstleria keralensis* C.N.Mohanan & N.C.Nair, in a sacred grove located in southern Kerala, as well as *Cinnamomum quilonensis* C.N.Mohanan & N.C.Nair, a rare cinnamon species found in a sacred grove in the Alappuzha district. Additionally, they identified several rare endemic species such as *Belpharistemma membranifolia* (Miq.) Ding Hou., *Buchanania lanceolata* Wight, and *Syzygium travancoricum* Gamble, along with the ecologically significant *Albizia lebbeck* (L.) Benth., and *Ficus glomerata* Roxb. in Kerala's sacred groves.

Vartak et al. (1986) stated that sacred groves conserve the forest resources of the Western Ghats. The increased atmospheric humidity and reduced temperature in these sacred groves, resulting from transpiration, create a favourable microclimate for various organisms. Moreover, it reduces the intensity of forest fires and satisfies the water requirements of many animals and birds through the ponds and streams adjoining the grove (Khiewtam and Ramakrishnan, 1989).

Ramachandran and Mohanan (1991) found wild cultivars of crop plants with better pest resistance and productivity were found in the sacred groves of Kerala. *Garcinia* sp., *Artocarpus* sp., *Piper* sp., and *Mangifera* sp. were some of the examples. Various studies have explored the floral diversity of Sacred Groves throughout the Western Ghats (Gadgil and Vartak, 1975, 1976 and 1981; Chandran and Gadgil, 1993a, 1993b; Unnikrishnan, 1995).

Induchoodan and Balasubramanian (1991) noted that sacred groves have been preserved in their original state for generations, forming a nationwide network of protected lands. As a result, they harbour relic vegetation and provide an excellent venue for studying endemism. While Prasad and Mohanan (1995) observed that sacred groves in Kerala do not overlap with forest areas, as they are distributed in the lowlands and midlands. Approximately 500 hectares of the forest area was made up of sacred groves, contributing to 0.05% of the overall forest area (Chandrashekara and Sankar, 1998a). The size of sacred groves varies from a few acres to over 20 hectares. The Iringole Kavu (20.00 ha), Kunnathurpadi Kavu, Payyanur (18.21 ha), and Theyyottu Kavu in Kannur district (16.19 ha) are examples of significant sacred groves in Kerala.

Past ecological research on the sacred groves of Kerala has been conducted by Induchoodan (1992), Rajendraprasad (1995), and Rajendraprasad et al. (1996, 1998).

Balasubramanyan and Induchoodan (1996) identified 761 sacred groves in Kerala, which together host a floristic diversity of over 722 species and 474 genera, including 153 endemic species unique to peninsular India. Induchoodan (1996) reported the presence of common species in these sacred groves, such as White dammar, Night-flowering jasmine, Black varnish tree, Niepa bark tree, Santa Maria tree, Ceylon Ironwood, and Tamarind; serpent worship was also a significant aspect of Kerala’s sacred groves.

Chandran et al. (1998) documented Wild turmeric (*Curcuma* sp.), wild ginger (*Zingiber* sp.), wild rice (*Oryza* sp.), and wild nutmeg (*Myristica malabarica* Lam.) in the sacred groves of Kerala. In contrast, Chandrasekara and Sankar (1998a) found

73 species in three sacred groves of Kerala, of which 13 are endemic to the Southern Western Ghats, 3 are endemic to the Western Ghats, and 1 is endemic to Peninsular India.

Basha (1998) provided a detailed account of the distribution and conservation importance of sacred groves in Kerala, noting that the vegetation found in these groves can be generally categorised into two types: evergreen and moist deciduous. As noted by Pushpangadan et al. (1998), the biological spectrum of Kerala's groves closely mirrors the typical biodiversity spectrum characteristic of tropical forests. Additionally, these groves serve as a vital source of water for the organisms that live within them and in the surrounding regions.

Induchoodan (1998) mentioned that sacred groves have a greater potential for biodiversity than the well-protected evergreen forests of South India. For example, a typical sacred grove spanning 1.4 km was home to 722 angiosperm species, while the Silent Valley Forest, which stretches 90 km, contains 960 species.

According to Rajendraprasad et al. (2000), Iringole Kavu exemplifies the midland vegetation typical of Kerala and has experienced moderate human disturbance. They identified a total of 124 species from 108 genera within this area. The prominent species include *Hopea ponga* (Dennst.) Mabb., *Mesua nagassarium* (Burm.f.) Kosterm., *Chassalia ophioxyloides* Craib, *Xanthophyllum arnottianum* Wight, and *Artocarpus hirsutus* Lam. The soil in this region was sandy loam, acidic, and rich in humus. The removal of deceased organic material was significantly limited. This site exhibits the characteristic three-stratum structure typically found in tropical evergreen forests.

Jayarajan (2004) highlighted the ecological importance of groves being refugees and biodiversity nuclei for many rare and endangered species of high relevance. At the same time, Sreedharan (2004) noted that each sacred grove is an inseparable part of traditional community life in Kerala. The soil was highly porous, with a thick litter cover and microfauna channels that enhance water-holding capacity, healthy plant root development, gaseous exchange, and heat conduction through plants and soil systems. He stated that recent studies indicate the presence of only 900 groves in Kerala, and organised religious interests, half-baked government policies and destruction of the joint family system are creating a threat to the existence of these sacred groves.

Sujana et al. (2006) documented 25 endangered plants found in the coastal sacred groves of Thrissur. Sujana and Sivaperuman (2008) said that sacred groves are home to threatened species that are used in indigenous medicine and recommended the conservation of natural vegetation in the coastal region of Kerala. Khan et al. (2008) agreed with this conclusion and stated that rare, endangered, threatened, and endemic species make them ideal locations for conserving biodiversity. The research also emphasised the important influence of religious beliefs on the preservation of these groves.

Shanthakumar et al. (2010) studied the biodiversity of the Iringole sacred grove and reported that it was once a tropical evergreen type forest patch, and now it has become a semi-evergreen type. A total of 210 species of angiosperms were reported from the grove. The grove is confined to several climber and straggler species, of which two are gymnosperms. *Artocarpus hirsutus - Hopea ponga - Vateria indica* L. association is a peculiarity of the Grove. 39 species of flowering plants identified in the grove were confined to peninsular India, of which most are Western Ghats endemics. And 12 species belonged to the red data list, like critically endangered (*Vateria indica*), Endangered (*Hopea parviflora* Bedd., *Hopea ponga*), Vulnerable (*Begonia trichocarpa* Dalzell), Rare (*Ampelocissus indica* Planch., *Vepris bilocularis* Engl.), Low risk (*Tabernaemontana alternifolia* L.) and Threatened (*Molineria trichocarpa* (Wight) N.P.Balakr.). Also, the study revealed that the grove was rich in invertebrate fauna. 10 species of butterflies, which come under high conservation status and nine species of spiders endemic to India were also reported from the grove.

Chandrashekara (2011) noted that there are primarily four major types of forests observed among the twenty-eight sacred groves studied, including evergreen, semi-evergreen, moist deciduous, and mangrove forests. The vegetation comprises 76% of the total grove area and was surrounded by agricultural lands, while some groves are adjacent to significantly degraded forests or barren regions. The current study also emphasised the importance of sacred groves in the religious and socio-cultural practices of the local community.

Warrier and Kunhikannan (2012) documented 687 plant species belonging to 493 genera from 1128 sacred groves located in Alappuzha. They identified two critically endangered tree species: *Vateria indica* and *Syzygium travancoricum*, along with a rare climbing legume, *Kunstleria keralensis*, and wild relatives of cultivated species such as *Trichosanthes cucumerina* L., *Myristica malabarica* Lam., *Garcinia xanthochymus* Hook.f. and *Buchanania lanceolata* Wight, the latter being a vulnerable species primarily found in sacred groves in Kerala. They asserted that even smaller groves demonstrated their importance by hosting rare and critically endangered tree species, highlighting the necessity for stringent protection regardless of their size.

Divya and Manonmani (2013) recorded 50 plant species having medicinal importance, from 8 sacred groves of Nenmara, Palakkad District. Jyothi and Nameer (2015) reported 111 species of birds from the sacred groves of Kannur District and Kasaragod District. Among them, two are endemic birds of the Western Ghats. Five species of raptors, four owl species and seventeen species of long-distance migratory birds were also reported.

Sreeja and Unni (2016) documented 245 flowering species from 209 genera in Vallikkaattu Kavu, located in Kozhikode District, Kerala. Among these species, 44 are endemic, and 34 are considered threatened. Of the 245 species documented, 236 possess medicinal properties, representing 96% of the flowering plants recorded in this sacred grove. Additionally, Jyothilakshmi et al. (2016) recorded 29 species of bryophytes from Vallikkattu Kavu, which includes 19 mosses and 10 liverworts. They recognised *Ditrichum tortuloides* Grout. as a new record for Peninsular India and *Bryum retusifolium* var. *heterophyllum* Card. ex. Gangulee as a new record for Kerala. The grove also hosts the endemic *Fissidens kammadensis* Manju, K.P.Rajesh & Madhus. and the rare *Calymperes palisotti* Schwaegr.

Notermans et al. (2016) noted that of the 50,000 sacred groves in India, only 2000 are located in Kerala. These sacred groves, historically preserved by communities due to their spiritual ties to the deities or ancestral spirits believed to inhabit them, are now at risk due to habitat loss and the loss of traditional belief. Amirthalingam (2016), Singh et al. (2017), and Alex (2018) agreed with this study and that only local people can ensure the conservation of sacred groves.

Chandrashekara et al. (2018) identified 418 angiosperm species, 36 species of VAM fungi from five genera - *Acaulospora, Gigaspora, Glomus, Scutellospora*, and *Sclerocystis* and 106 bird species alongside 151 butterfly species from Chamundi Kavu, Kammadam Kavu, Karimanal Mani Kavu, Poyil Kavu, and Valliyotu Kavu in Kerala, an area of the Western Ghats. Among these, 60 angiosperm species, 8 bird species, and 5 butterfly species were endemic to the Western Ghats. They also reported that sacred groves offer many benefits to rural communities. However, Soil studies showed a decrease in organic carbon, moisture content, and essential nutrients like N, P, K, Ca, and Mg due to anthropogenic disturbances. The researchers concluded that a natural resource conservation committee should be established for each sacred grove to protect and preserve the forest, water bodies, and biodiversity, and that in-depth scientific research is necessary to safeguard the habitat and its species. Sen (2019) agreed to this study and said that sacred groves are safeguarded by local communities due to their religious convictions, making conservation dependent on local participation. Also, Nair and Teji (2019) spotted 47 species of birds in Iringole Kavu. They pointed out that the food availability and the presence of a pond are the reasons for its rich bird fauna diversity.

Warrier (2018) declared Alappuzha as the Kedarnath of Sacred Groves. He said that 27 sacred groves were present in the Alappuzha district, where no natural forest was present. Also, 27 plants endemic to the Western Ghats were observed. George et al. (2018) identified 20 species of soil and leaf-spotting fungi across various sacred groves in central Kerala, including *Cercosporidium chaetomium* P.W. Crous and K. Seifert, which was a new record for Kerala. They also discovered *Cladosporium herbarum* (Pers.) Link on a new host, *Santalum album* L., which marked a new host record for the state.

2.2 Soil Fungi

2.2.1 In World - Several studies have taken place in the world to discover the fungal world. Some such studies are tabulated in the table given below (Table 1).

Table 1: Details showing the fungal diversity studies in the World

Sl. No	Author	Year	Title	Genus / Species Obtained	Dominated Genera	Remarks
1	Gocmen and Ozkan	2002	A research on the microfungal flora of some greenhouse soils in the vicinity of Lapseki Canakkale, Turkey	128 species	*Aspergillus, Penicillium, Geomyces, Exophiala, Fusarium*	Have phytopathological importance.
2	Grishkan and Nevo	2004	Soil Microfungi of Nahal Meitsar, ‘‘Evolution Canyon’’ Iv, Golan Heights	70 species	*Penicillium, Aspergillus, Fusarium, Acremonium, Chaetomium*	Mesophilic Penicillium dominated the microfungal communities.

3	Eliades et al.	2006	Soil microfungi in Celtis tala and Scutia buxifolia forests in eastern Buenos Aires Province (Argentina)	85 taxa, 39 species	*Fusarium solani*, *Fusarium oxysporum*	Nil
4	Singh et al.	2006	Psychrophilic fungi from Schirmacher Oasis, East Antarctica	16 fungal taxa	*Acremonium, Aspergillus, Cladosporium, Fusarium, Trichoderma*	Nil
5	Kara and Asan	2007	Microfungal community structure from forest soils in Northern Thrace Region, Turkey	Not specified	*Penicillium*	Fungi show variations in different ecosystems.
6	El-Said and Saleem	2008	Ecological and Physiological Studies on Soil Fungi at Western Region, Libya	30 genera, 63 species	*Alternaria, Aspergillus*	Nil
7	Buee et al.	2009	Pyrosequencing analyses of forest soils reveal unexpectedly high fungal diversity	Not specified	Not specified	Consists of Ascomycota and Basidiomycota.

8	Hujslova et al.	2010	Diversity of fungal communities in saline and acidic soils in the Soos National Natural Reserve, Czech Republic	39 genera	*Penicillium*	Nil
9	Zakaria et al.	2011	Diversity of Microfungi in Sandy Beach Soil of Teluk Aling, Pulau Pinang	7 genera	*Fusarium solani*	Nil
10	Grishkan and Nevo	2012	Spatiotemporal dynamics of culturable microfungi in soil of Mount Hermon, Israel	155 species	*Penicillium, Aspergillus, Phoma, Acremonium, Fusarium, Chaetomium*	Microenvironmental factors affect the diversity of fungi.
11	Alias et al.	2013	Diversity of microfungi in ornithogenic soils from Beaufort Island, continental Antarctic	10 fungal taxa	*Thelebolus microspores*, *Geomyces*	Nil
12	Hafizah et al.	2013	Studies on diversity of soil microfungi in the Hornsund area, Spitsbergen	38 fungal morphotypes	*Phialocephala, Mortierella, Geomyces, Atradidymella, Beauveria*	Nil

13	Abdullah and Nashat	2014	Diversity of Soil Microfungi in Pine Forest At Duhok Governorate, Kurdistan Region, Iraq	26 genera, 51 species	*Aspergillus, Penicillium*	*Absidia spinosa* and *Mucor plumbeus* are newly recorded from Iraq.
14	Kwasna and Nirenberg	2014	Microfungi in the soil of Scot pine forest in Poland and Germany	55 taxa	*Penicilium, Umelopsis, Oidiodendron griseum, Mortierella, Trichoderma*	Nil
15	Marescotti et al.	2014	Microfungi in a Cu-rich waste rock dump from an abandoned Fe-Cu sulphide mine (Libiola Mine, Eastern Liguria, Italy)	11 taxa	*Trichoderma, Clonostachys, Aspergillus*	Fungi can grow in copper-contaminated media.
16	Abneuf et al.	2016	Antimicrobial activity of microfungi from maritime Antarctic Soil	27 isolates	*Geomyces* sp.	Nil
17	Korneykova et al.	2017	Algae, cyanobacteria and microscopic fungi complexes in the Rybachy Peninsula soils,	12 species	*Penicillium decumbens*	Nil

			Russia			
18	Pudasaini et al.	2017	Microbial Diversity of Browning Peninsula, Eastern Antarctica Revealed Using Molecular and Cultivation Methods	104 genera	*Geomyces pannorum*	Ascomycota dominated followed by Basidiomycota and Zygomycota.
19	Mohammadian et al.	2017	Diversity of culturable fungi inhabiting petroleum-contaminated soils in Southern Iran	14 genera	*Alternaria, Exophiala, Aspergillus*	Nil
20	Yang et al.	2017	Diversity and distribution of soil micro-fungi along an elevation gradient on the north slope of Changbai Mountain	53 genera, 108 species	*Penicillium, Aspergillus, Trichoderma, Mucor, Rhizopus, Fusarium, Gliocaldium*	Nil
21	Herath et al.	2017	Exploration of Sri Lankan soil fungus for biocontrol properties	83 species	Not specified	Trichoderma species unveiled high enzyme and high antifungal activity.

22	Tafinta et al.	2018	Isolation and identification of soil Mycoflora in the upland and lowland soils of Usmanu Danfodiyo University, Sokoto, Sokoto state.	7 genera, 14 species	*Aspergillus Fusarium, Rhizopus, Saccharomyces, Trichoderma*	Nil
23	Rosas-Medina et al.	2020	Diversity of fungi in soils with different degrees of degradation in Germany and Panama.	150 species	*Trichoderma hamatum*, *Mucor moelleri* - Common species	Number and fungal diversity show variation in each country.
24	Diamandis et al.	2021	Fungal diversity in sacred groves vs. managed forests in Epirus, NW Greece	208 fungal taxa	Not specified	Sacred groves have high species richness.

2.2.2 In India – Fungal studies in India are given in the table below (Table 2).

Table 2: Details showing the fungal diversity studies in India

Sl. No	Author	Year	Title	Genus/ Species Obtained	Dominant Genera	Remarks
1	Rane and Gandhe	2006	Seasonal distribution of soil fungi from forest soils of Jalgaon District, Maharashtra	21 genera, 53 species	*Aspergillus*	Each forest is unique. Show seasonal differences in fungal diversity.
2	Kayang	2006	Soil Microbial Population Numbers in Sacred Grove Forest of Meghalaya, Northeast India	66 species	*Aspergillus, Penicillium*	Higher fungal population surface layer. Decreased along with soil depth. Maximum number in July.
3	Satish et al.	2007	Diversity of soil fungi in a tropical deciduous forest in	46 OTU	*Mortierella, Fusarium,*	The number of fungal colonies decreases by

			Mudumalai, Southern India.		*Penicillium*	about 50% in the dry season.
4	Majumder and Shukla	2008	Micro-Fungal Diversity in Soil of Three Different Agricultural Systems	34 genera, 80 species	*Aspergillus, Cladosporium, Geotrichum, Verticillium*	Nil
5	Gawas	2008	Studies on Diversity, Activity and Ecology of Microfungi Associated With Some Medicinal Plants of Goa Region of Western Ghats, India	Not specified	Hyphomycetous fungi	Nil
6	Panda et al.	2009	Influence of soil environment and surface vegetation on soil microflora in a coastal sandy belt of Orissa, India.	64 genera, 141 species	*Aspergillus, Penicillium, Trichoderma*	Nil
7	Saravanakumar and Kaviyarasan	2010	Seasonal distribution of soil fungi and chemical properties	25 genera, 76 species	Deuteromycetes	None of the basidiomycetes could

			of montane wet temperate forest types of Tamil Nadu			be isolated from these soils.
8	Madhanraj et al.	2010	An investigation of the mycoflora in the sand dune soils of Tamil Nadu coast, India	12 genera, 24 species	*Aspergillus, Penicillium, Fusarium*	Nil
9	Sharma	2010	Isolation of Soil Mycoflora of Katao near Gangtok, India	21 species	*Aspergillus*	Environment fungi are omnipresent. Get dominated by secreting enzymes in cold regions.
10	Guleri et al.	2010	Ecology of Rhizosphere and non-rhizosphere soil mycoflora of forest soils of Dehradun District Uttarakhand	23 genera, 57 species	*Aspergillus, Chaetomium, Mucor*	Nil
11	Sharma et al.	2010	Isolation of soil mycoflora of	22 species	*Aspergillus, Penicillium*	Nil

			Gangtok, India.			
12	Bhattacharyya and Jha	2011	Seasonal and Depth-wise variation in Microfungal Population Numbers in Nameri forest soil, Assam, Northeast India	14 genera, 21 species	*Aspergillus flavus, Penicillium chrysogenum*	Phycomycetes were dominant followed by Zygomycetes, Ascomycetes and sterile mycelia
13	Gomathi et al.	2011	Studies on Soil Mycoflora in Chilli Field of Thiruvarur District	18 genera, 40 species	*Aspergillus, Penicillium, Trichoderma, Fusarium, Chaetomium, Curvularia, Cladosporium, Rhizopus*	Deuteromycetes dominate followed by Ascomycetes and Phycomycetes.
14	Prince et al.	2011	An investigation of the soil mycoflora in sugarcane field of Thanjavur District-Tamilnadu	17 genera, 49 species	*Aspergillus niger*	Nil
15	Kalaiselvi and Panneerselvam	2011	Ecology of soil fungi in paddy field of Tamilnadu-Thanjavur district.	30 species	*Aspergillus, Trichoderma*	Nil

16	Nilima et al.	2011	Diversity of fungi from soils of Aurangabad, MS, India	45 genera, 85 species	*Aspergillus, Alternaria, Cladosporium, Trichoderma*	Nil
17	Majumder and Shukla	2012	Studies on Micro Fungal Diversity under Variable Habitats in Arunachal Pradesh.	64 species	*Penicillium, Aspergillus, Oidiodendron, Verticillium, Mortierella*	Consists of Ascomycetes, Deuteromycetes and Phycomycetes.
18	Devi et al.	2012	Diversity of Culturable Soil Micro-fungi along Altitudinal Gradients of Eastern Himalayas	Seven orders	*Penicillium, Aspergillus, Talaromyces, Fusarium*	Nil
19	Siddiqui	2012	Diversity of soil fungi from Kopergaon Tahsil, Dist.Ahmednagar (M.S.)	33 genera, 81 species	*Aspergillus, Penicillium, Alternaria, Curvularia, Drechslera, Fusarium*	Nil
20	Gaddeyya et al.	2012	Isolation and identification of soil mycoflora in different	6 genera, 15 species	*Aspergillus, Penicillium*	Nil

			crop fields at Salur Mandal			
21	Banakar et al.	2012	Diversity of soil fungi in dry deciduous forest of Bhadra Wildlife Sanctuary, Western Ghats of southern India	Not specified	Mitosporic fungi	Nil
22	Behera et al.	2012	Diversity of soil fungi from mangroves of Mahanadi delta, Orissa, India	14 genera, 22 species	*Fusarium, Penicillium*	Mangrove soil is a potential substrate for the growth of fungi.
23	Guleri et al.	2014	Soil Mycofloral Diversity under Wheat Cultivation in Doon Valley, Uttarkhand	11 genera, 23 species	*Aspergillus, Alternaria, Cochliobolus, Rhizopus*	Surface soils have higher microfungal diversity than deeper profile.
24	Devi and Dkhar	2014	Comparative study on soil fungal diversity of Mawphlang Sacred grove and disturbed forest Northeast India	75 fungal taxa	Ascomycota	They got more fungal taxa from sacred groves than from a disturbed forest.

25	Sharma et al.	2015	Fungal diversity of twelve major vegetational zones of Arunachal Himalaya, India	59 genera, 88 species	*Aspergillus, Penicillium*	Sub-tropical evergreen forests showed maximum fungal diversity followed by tropical evergreen forests and tropical semi-evergreen forests.
26	Kumar et al.	2015	Isolation and identification of soil mycoflora in agricultural fields at Tekkali Mandal in Srikakulam District	6 genera, 18 species	*Aspergillus, Penicillium*	Nil
27	Gnanasekaran et al.	2015	Isolation and identification of soil mycoflora in banana field at Manachanallur, Tiruchirappalli Dt., Tamil Nadu, India	26 genera, 65 species	*Aspergillus, Penicillium, Trichoderma, Absidia*	Deuteromycetes dominate followed by Ascomycetes and Phycomycetes.

28	Ashok et al.	2015	Diversity and Seasonal Variation of Soil Fungi Isolated from Coastal Area of Tuticorin Dt., Tamil Nadu, India.	16 genera, 42 species	*Aspergillus, Fusarium, Curvularia*	Deuteromycetes dominate the population followed by Phycomycetes.
29	Fernandes et al.	2015	Diversity of mycoflora in mangrove soils of Karankadu, Tamil Nadu, India.	21 genera, 58 species	*Aspergillus, Penicillum, Curvularia*	Deuteromycetes dominate the isolate followed by Phycomycetes.
30	Guleri et al.	2016	Occurrence and Diversity of Soil Mycoflora in Some Selected Brassica Growing Agricultural Fields of Dehradun District of Uttarakhand, Himalaya	11 genera, 26 species	*Aspergillus, Alternaria, Eurotium, Fusarium, Mucor, Rhizopus*	Microfungal diversity is higher in surface soils than in deeper profiles.
31	Patil and Barabde	2016	Studies on Soil Mycoflora in Different Agricultural Field of	5 genera,13 species	*Aspergillus, Penicillium*	Maximum fungal species belong to Ascomycetes and

			Buldhana District (Ms)			Zygomycetes.
32	Kumar Seth et al.	2016	Isolation and identification of soil fungi from wheat cultivated area of Uttar Pradesh.	Not specified	*Aspergillus, Penicillum, Geotrichum*	Nil
33	Paulina et al.	2016	Studies on soil mycoflora in different tomato fields of four districts in Tamil Nadu, India.	6 genera, 16 species	*Aspergillus, Penicillium, Mucor*	Maximum fungal species belong to Ascomycetes and Zygomycetes.
34	Chandini and Rajeshwari	2017	Isolation and identification of soil fungi in Mattavara forest, Chikamagalur, Karnataka.	32 genera, 82 species	*Penicillium, Aspergillus, Chaetomium, Trichoderma, Fusarium*	First report on the diversity of soil fungi in Mattavara forest of Chikkamagaluru, Karnataka.
35	Ramkumar et al.	2017	Studies on the Diversity and Incidence of Soil Fungal Communities in Different	11 genera, 19 species	*Aspergillus, Penicillium*	Wetness of the paddy field and environmental factors

			Cultivated Lands.			harbour a greater number of fungi in the paddy fields.
36	Raja et al.	2017	Isolation and identification of fungi from soil in Loyola College campus, Chennai, India	13 species	*Aspergillus, Mucor*	Nil
37	Lanjewar	2019	Isolation and Identification of Soil Mycoflora in Different Agriculture Fields of Tilda, Raipur (C.G.).	15 genera, 38 species	*Aspergillus Penicillium, Fusarium, Curvularia*	Deuteromycetes dominates followed by Ascomycetes and Phycomycetes.
38	Bandgar and Patil	2019	Ecological role of leaf litter fungi in Gangoba Sacred Grove Hasane, from Radhanagari Tehsil (Dist. Kolhapur).	14 genera, 39 species	*Aspergillus Rhizopus, Fusarium, Mucor*	Nil

2.2.3 In Kerala - Upon examining Kerala, the southernmost state in India, we found very few studies regarding the diversity of soil fungi. The studies conducted in Kerala are listed in the table below (Table 3).

Table 3: Details showing the fungal diversity studies in Kerala

Sl. No	Author	Year	Title	Genus/ Species Obtained	Dominant Genera	Remarks
1	Sankaran and Balasundaran	2000	Soil Microflora of Shola Forests of Eravikulam National Park	34 genera, 101 species	*Penicillium, Aspergillus, Trichoderma*	13 species formed new records and 11 species were rarely recorded from India.
2	Deshmukh	2003	Incidence of keratinophilic fungi from selected soils of Kerala state (India)	8 genera, 15 species	*Chrysosporium, Arthroderma*	Nil
3	Gilna and Khaleel	2011	Diversity of fungi in mangrove ecosystem	11 species	*Aspergillus*	The mangrove ecosystem is the ideal environment for a diverse composition of fungal isolates.

4	Mini et al.	2012	Keratinophilic fungal diversity of soil from Ernakulam and Thrissur districts – Kerala	5 genera, 15 species	*Aspergillus*	Nil
5	Mohamed and Nair	2016	Diversity of Soil Fungi in Kumarakom Bird Sanctuary, Kerala.	13 genera, 28 species	*Penicillium, Aspergillus*	Ascomycetes dominate the population followed by Zygomycetes and Oomycetes.
6	George et al.	2018	Sacred Groves: Treasure House Of Leaf Spotting and Soil Fungi	9 species	Not specified	*Cercosporidium chaetomium* was a new species recorded to Kerala. *Graphium putredinis, is* the only species of *Graphium* from Kerala.
7	Shankar et al.	2018	Biodiversity of xylanase producing fungi present in the leaf litter soil of Munnar hills, Kerala	Not specified	*Rhizopus, Aspergillus, Fusarium*	*Fusarium sporotrichoides,* the potential xylanase-producing fungi.

2.3 Ecology of soil fungi

Tresner et al. (1954) stated that fungal species richness increases from the pioneer to the climax forest. While *Penicillium* demonstrates a consistent rise from pioneer to climax forests, the proportion of Mucorales diminishes as one moves from pioneer to climax forests. They also found a correlation between the fungal population and the organic matter and moisture content levels in the soil. Certain species displayed seasonal peaks in density and frequency, although there were minimal seasonal variations among fungal species.

Griffin (1963) reported that fungi can grow in soil drier than the wilting point of plants. Also, they said that factors such as moisture content, texture, and structure influence the soil fungi, whereas excess carbon dioxide and deficient oxygen will affect fungi. Shameemullah et al. (1971) observed that the pF range of 1.9 to 2.3 was the optimal soil moisture range for all fungal species. Below and above that range resulted in a marked reduction in the fungal population. *Trichoderma viride* and *Penicillium* sp. can grow in various soil moisture conditions. They also reported that available nitrogen and potassium are strong predictors of the fungal community.

Lee and Baker (1972) pointed out that salinity, waterlogged conditions and hydrogen sulphide influence the fungal distribution. Lucarotti et al. (1978) found that the differences in species frequencies after a fire across various sites are affected by environmental factors associated with the build-up of organic matter and its incineration by fire.

Bissett and Parkinson (1979) noted that abiotic factors such as temperature, pH, moisture, and available potassium affected the distribution and community structure of soil fungi in three distinct alpine environments. Seasonal fluctuations in the composition of mycoflora were linked to variations in soil moisture and temperature conditions. In the spring, low temperature was a limiting factor, whereas low moisture was the constraint during the fall.

Rao and Venkateswarlu (1983) stated that organic matter and moisture content show a positive correlation with the population of microorganisms. The availability of mineral nutrients decreases during the peak vegetation growth of the monsoon season, making it more difficult for microbes to access them. Consequently, the microbial population was reduced during the rainy season.

Chauhan et al. (1985) said that soil moisture, water-holding capacity, and organic matter show a negative correlation with the number of fungi, whereas pH and exchangeable sodium show a positive correlation with the number of fungi. Nitrogen, exchangeable calcium, and potassium show no correlation.

Widden (1986) observed that summer and winter are challenging periods for many fungi, while spring and fall may be more favourable for their growth.

Fresquez et al. (1988) stated that an increase in the number of fungi correlated with a decrease in soil pH and an increase in total N, P, and organic matter. Their study also revealed that shrubs and grasslands have higher fungal diversity and evenness than tree land.

Arunachalam et al. (1999) observed that the fungal population, soil nutrient levels, soil respiration, and dehydrogenase activity were higher in sacred groves compared to grassland, and were significantly influenced by various soil properties, especially nutrient levels.

Satish et al. (2007a) reported that the soil fungal population in Mudumalai was not correlated with most of the edaphic factors except soil pH and soil temperature. And these 2 factors show exceptions in only one season, while the mean population density of soil fungi doesn’t show a significant difference in the 2 seasons.

Lauber et al. (2008) said that fungal composition was influenced by nutrient status of soil. The variation in soil physicochemical characteristics resulted in the variation of fungal communities and was positively correlated to soil moisture content (Majumder and Shukla, 2008).

Panda et al. (2009) found in their research that the surface layer, where there are higher soil nutrients and lower moisture levels, harbours a greater abundance of fungi, as well as during the rainy season, compared to summer and winter. They noted that the fungal population has a positive relationship with overall soil respiration, total organic carbon, and moisture content, but a negative relationship with soil temperature.

Saravanakumar and Kaviyarasan (2010) noted that moisture and organic content in soil were consistently high throughout all seasons, while electrical conductivity and pH remained unchanged across the seasons. They observed that the concentration of micro and macronutrients gradually rose during the summer rains. The population of fungi was greater during the rainy season. Therefore, they demonstrated that a decline in soil micro and macronutrients corresponds with a reduction in the number of fungal colonies. In contrast, Madhanraj et al. (2010) reported that there was no notable correlation between fungal populations and the pH, moisture content, available nitrogen, or organic carbon in the soil, although electrical conductivity and water holding capacity showed a positive correlation with fungal populations. Rousk et al. (2010) echoed this research, stating that fungal diversity was only weakly connected to soil pH, as fungi can thrive in a broader pH range.

Guleri et al. (2010) reported that the forest soils of Dehradun, Uttarakhand, have unique mycoflora, which shows seasonal differences. Fungal diversity was maximum in the summer season and minimum in the winter and rainy seasons. The study concludes that fungal growth was favoured by high temperatures.

Bhattacharyya and Jha (2011) reported that organic carbon, moisture content, pH, total N concentration, and available K are positively correlated with the density of soil fungi of Nameri forest, Assam, India. They stated that this may be the reason for a higher fungal population on the soil surface, and the fungal population decreases with depth. Kalaiselvi and Pannerselvam (2011) supported this study by stating that several environmental factors like moisture content, organic matter and pH influence the soil fungi, and they are high in the rainy season and on the soil surface.

Siddiqui (2012) reported that the suitable pH for the growth of soil fungi was 7–9, and the ideal temperature for the growth was 28°C. Also, said that the winter season shows a higher fungal population, followed by the rainy and summer seasons. The difference in fungal flora was due to the difference in soil, organic carbon, moisture content, soil texture, type, humidity, vegetation, salinity, temperature, and pH of respective seasons. Gaddeyya et al. (2012) and Grishkan and Nevo (2012) also supported this study. Banakar et al. (2012) stated that fungal diversity changes with season and was highly influenced by soil physicochemical parameters. Also, they observed that fungal diversity was higher in the winter and monsoon seasons. Devi et al. (2012) also supported the study. They stated that fungal distribution was positively correlated with temperature, humidity, and pH, whereas moisture content and altitude show a negative correlation.

Tedersoo et al. (2015) reported that climatic factors are the most significant predictors of soil fungal diversity and composition. The study stated that tropical ecosystem shows high fungal diversity and fungal endemism. The fungal richness was strongly influenced by the mean annual precipitation and distance from the equator. Devi and Dkhar (2014) noted that sacred groves contained higher levels of soil organic carbon and available phosphorus compared to disturbed forests, and that soil temperatures were lower in sacred groves. In sacred groves, soil temperature, moisture content, and organic carbon showed a positive correlation with fungi, whereas soil temperature and exchangeable potassium showed a positive correlation with fungi in disturbed forests.

According to Sharma et al. (2015), fungi were negatively correlated to the altitudinal gradient. At the same time, Gnanasekaran et al. (2015) reported that cation exchange capacity and calcium and potassium availability show a positive correlation with fungal diversity and distribution. Meanwhile, Jena et al. (2015) observed that moisture content and organic carbon influence the fungal population. The fungal diversity was higher in the summer region. According to Fernandes et al. (2015), the available phosphorus shows a positive correlation with fungal population, whereas the electrical conductivity and cation exchange capacity show a negative correlation with fungal colonies.

Paulina et al. (2016) said that the frequency of soil fungi was influenced by factors like soil texture, pH, organic carbon, temperature, soil salinity, and inorganic materials. Mohamed and Nair (2016) stated that the high fungal population in the perching area of birds in Kumarakom Bird Sanctuary was due to the high moisture content and presence of bird droppings in that area.

Yang et al. (2017) reported that with increasing elevation, the micro-fungal richness shows a significant decrease and was related to the difference in altitude, the change in forest types and climate. Whereas, Chandini and Rajeshwari (2017) reported that optimum moisture content, acidic pH, rich organic matter, and slit and clay soil are the much-needed conditions for fungal growth. They concluded that recycling dead organic matter and thus making it available for the next generation was the true purpose of fungi in nature. He et al. (2017) also supported the study. They stated that with latitude, soil fungal diversity increased linearly or parabolically. The temperate deciduous forest shows more seasonal variation in fungal diversity than the subtropical evergreen forest.

Aziz and Zainol (2018) stated that *Aspergillus aculeatus* and *Paecilomyces lilacinus* identified from flooded soil enhance plant growth by increasing nutrient availability in soil.

Castano et al. (2018) reported that autumn shows higher soil fungal diversity, followed by summer and late winter seasons. The changes in soil temperature and moisture were attributable to this seasonal variation. Tafinta et al. (2018) observed that lowland uncultivated soil has the highest number of fungi, followed by upland uncultivated soils and upland cultivated soils. They concluded that low nutrient levels and high organic carbon influence fungal diversity, along with agricultural practices.

Bandgar and Patil (2019) indicated that fungi play a crucial role in soil nutrient recycling and enhancing soil fertility by breaking down leaf litter. They noted that fungi are vital for maintaining the rich and diverse plant life found in sacred groves.

Lanjewar (2019) found that there was a positive relationship between cation exchange capacity and the availability of potassium and calcium with the diversity and distribution of soil fungi. Rosas-Medina et al. (2020) observed that geography was the key factor influencing soil fungal populations, rather than the properties of the soil itself. They concluded that soil degradation does not impact the communities of soil fungi found in Germany and Panama.

Sui et al. (2022) revealed that the structures of fungal communities are mainly influenced by available phosphorus, available nitrogen, and total nitrogen in the soil.

They said that soil quality and characteristics show variation between forests having different species.

2.4 Metagenomics Study

Fierer et al. (2007) said that the metagenomics study revealed that soil fungi, archaea, viruses, and bacteria are globally as well as locally diverse.

De Castro et al. (2008) observed that anthropogenic activity resulted in the decline of the number of fungal OTUs in the Cerrado and nearby agricultural fields in Brazil.

Buee et al. (2009) investigated six distinct forest soils utilising 454 pyrosequencing, and the research determined that Basidiomycota was the predominant phylum, followed by Ascomycota. The primary fungal class identified was Agaricomycetes, while the most prevalent species included *Cryptococcus podzolicus*, *Ceratobasidium* sp., *Scleroderma* sp., and *Lactarius* sp. High quantities of uncultured fungi were also found. The study concluded that soil metagenomics offers valuable insights into the taxonomic and functional diversity of soil microorganisms.

Sangwan et al. (2012) observed the genus *Fusarium* from the hexachlorocyclohexane dumpsite, and their study became the first metagenomics analysis of samples collected from soils with differential concentrations of hexachlorocyclohexane contamination.

Fierer et al. (2012) reported that the fungal communities from the cold desert had the lowest functional, phylogenetic and taxonomic diversity and had fewer antibiotic-resistance genes.

Kim et al. (2013) recorded Ascomycota, Zygomycota, Basidiomycota, Chytridiomycota, and Glomeromycota from the fairy ring zones of *Tricholoma matsutake* using metagenomics analysis. Agaricomycetes dominated the fungal class. They observed that fungal diversity was lower in the fairy ring zone when compared to the other zones.

Orellana (2013) stated that the metagenomics approach has several limitations, as it was unable to differentiate between living and dead microbial cells, or between active and inactive ones. Additionally, the computational assembly of metagenomic data carries the risk of generating chimeras, which must be addressed.

Geml et al. (2014) reported high fungal diversity and some red-listed fungi from the beds of *Salix repens* coastal dune in the Netherlands. Soil pH exhibits a positive relationship with fungal composition, while it demonstrates a negative relationship with the number of OTUs. Ascomycota was the dominant phylum, followed by Basidiomycota Glomeromycota, Mucoromycotina, Incertae sedis and Chytridiomycota. Helotiales and Agaricales dominates the order.

LeBlanc et al. (2015) indicated that the characteristics of the soil and the dynamics of plant communities had a significant impact on the fungal community. In plant communities, fungal diversity was greater in polyculture compared to monoculture.

Tedersoo et al. (2015) highlighted that using internal transcribed spacer (ITS) barcodes provides better taxonomic and functional resolution, resulting in a higher richness of operational taxonomic units (OTU).

A research study by Vargas-Gastelum et al. (2015) found that the structure of fungal communities exhibited less variability across different seasons in burrows compared to topsoil in a semi-arid region of Baja California, Mexico. They indicated that the variations in composition among microhabitats were largely attributed to notable differences in moisture and clay content in the topsoil samples, as well as temperature and electrical conductivity in the burrow samples.

Nam et al. (2015) found that species richness was higher in Ulleungdo Island than in the Dokdo Islands. Phylum Ascomycota dominates the Dokdo Island, whereas phylum Basidiomycota dominates in Ulleungdo Island. Agaricomycetes are closely related to the richness and diversity of vascular plants.

Simoes et al. (2015) recorded several soil fungal species new to the red sea grey mangroves. Ascomycota predominates the phylum, followed by Basidiomycota.

De Castro et al. (2016) reported that the soil fungal community structure of Cerrado, Brazil, was strongly influenced by vegetation coverage, soil moisture, soil water uptake and seasonal changes. During the rainy season, there was a reduction in the relative abundance of Glomeromycota and unclassified fungal sequences, while the presence of Ascomycota increased. The relative abundance of Saccharomycetes and Agaricomycotina differed significantly with soil moisture content.

Zhang et al. (2016) observed that Ascomycota was the dominant phylum, followed by Basidiomycota, Chytridiomycota, Glomeromycota, Zygomycota, and Rozellomycota. Helotiales dominate the order, followed by Verrucariales and Agaricales. *Fusarium*, *Tetracladium*, *Mortierella*, *Atla,* and *Cortinarius* became the common genera. They revealed that soil pH determines the fungal composition in the Ny-Alesund Region, Svalbard.

Castaneda and Barbosa (2017) reported that Ascomycota predominates the phylum, followed by Basidiomycota. *Gibberella* was the dominant genus in these soils, and species richness was higher in vineyards than in forests. They stated that forests, as microbial reservoirs, buffer the effects of land conservation.

Edet et al. (2017) highlighted that the limitations of metagenomics include insufficient interdisciplinary collaboration, methodological difficulties, challenges in data analysis and archiving, as well as the inability to culture microbes from environmental samples and issues with DNA extraction methods. Hence, a global metagenomics initiative was needed to expand the applications of metagenomics.

Moussa et al. (2017) observed a total of 460 fungal species from the western coastal regions of Saudi Arabia. Ascomycota dominated the phyla, followed by Basidiomycota, Chytridiomycota and Glomeromycota. Sordariomycetes and Pezizomycetes dominate the class. Genus *Thielavia* predominates the genera, followed by *Madurella*, *Aspergillus*, and *Gelasinospora*.

Baeza et al. (2017) recorded 87 genera and 123 species of fungi, of which 37 fungal species were new to Antarctica. Lecanoromycetes and Eurotiomycetes dominate the class. The study concluded that metagenomics was the best option for the broad study of microbial communities in extreme environments.

Narendrula-Kotha and Nkongolo (2017) reported that Ascomycota was dominant in the metal-contaminated soil, whereas Basidiomycota was dominant in the reference areas. The study concluded that metals alter soil ecosystem diversity, structure, and function, as microbial biomass and abundance show a significant reduction in the contaminated sites.

Roshni and Harikumar (2018) identified *Candida africana* followed by *Alternaria alternata*, *Edenia gomezpompae*, *Aspergillus niger,* and *Neolentinus lepideus* from the paddy fields Kuttanad, India, using Next Generation Sequencing. Less abundant fungal species were *Acaulospora colombiana* and *Candida sake.* The study states that fluoride-tolerant fungi can be used to ameliorate fluoride toxicity in paddy fields.

Haldar and Nazareth (2019) indicated that the mangrove sediments in Goa, India, possess similar fungal phyla, but the species abundance varies. The two primary phyla identified were Basidiomycota and Ascomycota, with the classes Agaricomycetes, Sordariomycetes, Saccharomycetes, Dothideomycetes, and Eurotiomycetes being the most dominant. The sediment in Zuari was found to be taxonomically diverse, suggesting the presence of potential candidates for bioremediation.

Noor et al. (2021) compared the fungal rhizosphere communities of some desert plants and observed that Ascomycota was the dominant phylum. Sordariomycetes and Dothideomycetes dominate the class. Eurotiales dominate the order, followed by Hypocreales and Pleosporales. Trichomaceae was the dominant family, followed by Didymellaceae and Ceratobasidiaceae. *Aspergillus, Ceratobasidium, Fusarium,* and *Penicillium* were the abundant genera.

An et al. (2021) recorded 6 phyla, 29 classes, and 164 genera of fungi from the *Trichoderma matsutake* production and nonproduction soils of the Bonghwa and Yanyang regions. Ascomycota, Basidiomycota, Mortierellomycota, and Mucoromycota were common in all soils. Dothideomycetes, Eurotinomycetes, Leotiomycetes, and Sordariomycetes were the common classes. Genus *Tricholoma* was the most dominant genus. They stated that species diversity was lower in *T. matsutake* production soil than in the other soil.

Pang et al. (2021) identified 485 fungal species belonging to 282 genera, 165 families, 78 orders, 33 classes and 10 phyla from three sugarcane soil samples.

Ascomycota was the dominant phylum, followed by Basidiomycota and Chytridiomycota. The proportion of Ascomycota increases, whereas that of Basidiomycota and Chytridiomycota decreases with continuous cropping. *Penicillium, Talaromyces, Mycena, Fusarium*, and *Aspergillus* were the abundant genera, and *Penicillium* and *Aspergillus* increased in proportion with cropping.

Rayko et al. (2021) reported a significant diversity of species in the Chernevaya taiga soils located in western Siberia. The most prevalent phylum was Glomeromycota. They concluded that the high productivity and large plant sizes in the Chernevaya taiga were attributed to the widespread presence of Glomeromycota, which are recognised for forming symbiotic associations that promote plant growth.

Passarini et al. (2022) reported that in the heavy metal-contaminated soil, Ascomycota was the dominant phylum, followed by Basidiomycota, Chytridiomycota and Blastocladiomycota. A relatively low abundance of the fungal community was seen in soil with high lead contamination. *Aspergillus, Chaetomium,* and Saccharomycetales dominate the soil, indicating their potential for bioremediation.

Chapter 3

Materials and Methods

3.1 Soil Sampling

Soil samples were collected from selected sacred groves in Kerala across three seasons over a two-year period: Pre-Monsoon, Monsoon, and Post-Monsoon. Samples were taken aseptically from a depth of 0 to 10 cm using a composite soil sampling method. The sacred grove was divided into four areas, with the number of samples taken from each area based on the size of the grove. Samples from each area were combined and thoroughly mixed to create a single set of soil samples per area, resulting in four samples in total from the grove. The soil samples were stored in polythene bags inside cooler boxes packed with ice blocks and carried to the laboratory for subsequent analysis.

3.2 Isolation of Fungus

Soil samples were air-dried and then passed through a mesh with a pore size of 2 mm. These samples were subjected to the soil dilution plate method (Waksman, 1922). A total of 10 g of soil was placed in a sterilised beaker with 100 ml of distilled water and mixed well. The soil samples were serially diluted, and dilutions of 10^{-3} and 10^{-4} were selected to isolate the fungi, thereby avoiding overcrowding of fungal colonies. Using a micropipette, 1 ml of the desired dilutions was aseptically pipetted into sterilised petri plates, prepared in triplicate for each dilution. Each petri plate contained 12 to 15 ml of molten Potato Dextrose Agar (PDA) medium, which was amended with Chloramphenicol at a concentration of 0.050 g/l, as well as Czapek Dox Agar (CDA) medium prepared in the same manner. The aliquots in the petri plates were spread evenly using a sterile spreader and then incubated in an incubation chamber with a 12-hour light and 12-hour dark cycle at 28±2°C for five to seven days.

Hyphal tips from individual fungal colonies growing on PDA and CDA were collected using a fine-tipped sterile needle. They were inoculated individually onto petri plates containing PDA, amended with Chloramphenicol (0.050 g/l) to achieve pure cultures. These plates were then incubated and monitored for 14 days. Photographs of the petri plates were taken using a Canon Eos R digital camera.

A slide culture was prepared from the fungal pure cultures. For this step, hyphal tips from the centre of the pure cultures were picked with a fine-tipped sterile needle and inoculated into water agar on a sterile glass slide, which was then covered with a sterile cover slip. The slide was incubated inside a closed sterile tray containing wet tissues to maintain moisture for three days. The fungus-covered coverslip was later transferred to a sterile glass slide with lacto-phenol cotton blue stain and maintained in the Laboratory, Department of Botany, St. Thomas College (Autonomous), Thrissur. The slide culture was observed under a Leica DM2000 LED microscope, and photomicrographs were taken using the attached Leica DMC2900 camera. Fungal colonies that failed to produce reproductive structures on PDA were classified as non-sporulating fungal isolates (NSF), and these NSF isolates were examined for their morphological characteristics.

3.3 Taxonomic Descriptions and Identification

Colony characteristics, such as colony growth, colour, and features on both the upper and lower sides of the plates, were observed on alternating days until the 14^{th} day. The slide cultures were examined, and the morphological traits of the mycelium, fruiting bodies, and spores/conidia were recorded. Additionally, the lengths of the hyphae, as well as the length and breadth of the spores, were noted.

Fungal species were identified using standard identification manuals, including works by Barnett (1960), Raper and Thom (1949), Raper and Fennell (1965), Gilman (1956), Ellis (1971, 1976), Barnett and Hunter (1972), Domsch and Gams (1972, 1980), Sutton (1980), Von (1981), Subramanian (1983), and Ramarao and Manoharachary (1990), as well as Watanabe (2017). Several comprehensive research papers on fungal taxonomy were also utilised (Samson et al., 2014; Visagie et al., 2014; Hughes, 1978; Bhat and Kendrick, 1993; Subramanian, 1987; Rao and de Hoog, 1986). Furthermore, electronic resources such as Index Fungorum, Mycobank, Science Direct, Shodhganga, and Wiley were referenced.

3.4 Quantitative Analysis

The quantity of colonies formed on dilution plates was counted, averaged and multiplied by the dilution factor (10^{-3}) to determine the number of Colony Forming Units (CFU g^{-1}) in the soil sample. To calculate the serially diluted Colony Forming Units in the power of 10^{-3} in triplicate, individual species' colonies were counted, averaged with the total number of colonies formed on the dilution plates, and multiplied by 100.

3.5 Diversity Analysis

Alpha diversity indices such as Chao 1, Simpson's dominance index (1-D), Shannon Weiner index (H), Pielou's Evenness index and Margalef Richness index were measured to reveal the seasonal and spatial variation in the fungal diversity.

3.6 Multivariate Analysis

To assess the similarity or dissimilarity in diversity between the two communities, Hierarchical Cluster Analysis (HCA) and Non-metric Multidimensional Scaling (NMDS) analysis were performed. HCA utilises the Bray-Curtis similarity index, a measure of beta diversity, to group sites and seasons based on the fungi observed in the study. NMDS provides a 2D plot that displays sites or seasons with similar species distributions arranged closely together. This analysis helps to visualise a multidimensional distance matrix in two dimensions. All analyses were performed using PAST 4.13 (Paleontological Software Package) across different seasons and sites, focusing on species composition and abundance.

3.7 Physicochemical Analysis of Soil

Soil samples were aseptically collected from a depth of 0 to 10 cm at various sites within each sacred grove. These samples were pooled together to create a single representative sample from each grove. They were then placed in polythene bags and stored in cooler boxes packed with ice blocks for transportation to the laboratory, where physicochemical analysis was conducted. A total of 12 different soil characteristics were analysed in the three seasons for two years.

The physicochemical parameters analysed included Temperature, pH, Moisture Content, Organic Carbon, Electrical Conductivity, Water Holding Capacity, Available Nitrogen, Available Phosphorus, Available Potassium, Exchangeable Ca, Exchangeable Na, and Texture, all measured using standard procedures and instruments.

Table 4. List of instruments and analytical methods followed for soil analysis

Sl. No	Parameters	Method	Instrument
1	Soil Temperature (°c)	Thermometry	Soil Thermometer
2	pH	pH Metry	pH Meter
3	Moisture Content (MC) (%)	Wet Basis Moisture Content	Microwave oven & Weighing Balance
4	Organic Carbon (OC) (%)	Walkley Black acid digestion method	Burette and Pipette
5	Electrical Conductivity (EC) (dS/m)	Electrometry	Conductivity Meter
6	Water Holding Capacity (WHC) (%)	Keen Rascowzkii method	KR Box
7	Available Nitrogen (kg/ha)	Alkaline Potassium permanganate method	KEL PLUS Nitrogen Estimation System
8	Available Phosphorus (kg/ha)	Colourimetry	Spectrophotometer
9	Available Potassium (kg/ha)	Flame Photometry	Flame Photometer
10	Exchangeable Ca (Cmol/kg)	Atomic Absorption Spectrophotometry	Atomic Absorption Spectrophotometer
11	Exchangeable Na (Cmol/kg)	Flame Photometry	Flame Photometer
12	Soil Texture	Hydrometer method	Hydrometer

Univariate analyses, including the Mean, Range, Standard Deviation, and Standard Error of physicochemical parameters recorded from various sites and seasons, were conducted using Microsoft Excel. A One-way Analysis of Variance (ANOVA) was performed at a 5% significance level to evaluate the significant effects of season and site on these parameters. The Pearson Correlation Coefficient was calculated at a 5% significance level to statistically evaluate the relationships between parameters, utilising PAST 4.13 software, and a correlation plot was created.

3.8 Correlation Analysis

3.8.1 Canonical Correspondence Analysis

To explain the relationships between fungi and different environmental parameters, a multivariate analysis known as Canonical Correspondence Analysis (CCA) was conducted. CCA helps determine the correlation between fungal dynamics and various parameters across different seasons and sites. The primary objective of CCA was to identify the most significant physicochemical parameters that influence the distribution of fungi. The analyses were performed using PAST 4.13 software.

3.8.2 Indicator Species Analysis

An analysis of indicator species was conducted to determine which species reflect the qualities of a particular environment. This analysis helped reveal the indicator species across different seasons and locations. The table of p-values indicates that taxa with a p-value of 0.05 or lower are regarded as significant indicators. The analyses were performed using PAST 4.13 software.

3.9 Metagenomics Study using Next Generation Sequencing Technology

3.9.1 Soil Sampling, DNA Extraction and PCR Amplification

Soil samples were collected aseptically from 0 to 10 cm depth from different sites of each sacred grove and were pooled together to make a sample from each grove. It was kept in polythene bags inside cooler boxes packed with ice blocks and was carried to the laboratory for metagenomics analysis.

Genomic DNA was extracted using the soil DNA isolation kit (DNeasy Power Soil Kit, QIAGEN, Hamburg, Germany) in accordance with the manufacturer's protocols. PCR reactions were carried out in 50µl reaction mixtures (Emerald Amp GTPCR Master Mix) as per the manufacturer's instructions with 10 picomols of forward and reverse primers each. ITS 1–4 genes were amplified using the specific primers [ITS 1 (TCCGTAGGTGAACCTGCGG) and ITS 4

(TCCTCCGCTTATTGATATG)] with the barcodes. PCR amplification was carried out on a thermal cycler (BIORAD, USA) following this protocol: 35 cycles of 95°C for 3 minutes, then 95°C for 15 seconds, 56°C for 30 seconds, 72°C for 30 seconds, 72°C for 5 minutes, followed by a hold at 4°C. The PCR products were evaluated through electrophoresis on a 2% agarose gel. Samples displaying a prominent single band at around 500 bp were selected for further experimentation, followed by bead-based purification.

3.9.2 Library Preparation, Sequencing and Data Processing

Sequencing libraries were constructed using the NEB Next® Ultra™ DNA Library Prep Kit (NEB, USA) according to the manufacturer's instructions, with index codes incorporated. The quality of the library was evaluated using the Qubit@ 4.0 Fluorometer (Thermo Scientific) and the Agilent Bioanalyzer 2100 system. The library was sequenced on an Illumina MiSeq platform, producing 250 bp paired-end reads.

The resulting paired-end sequences were processed using the QIIME2 tool (version 2022.2.0) (Bolyen et al., 2019). The "Dada2" algorithm (Divisive Amplicon Denoising Algorithm, version 2) (Callahan et al., 2016) was employed to filter phiX reads and chimeric sequences from the Illumina amplicon sequence data and to obtain the number of sequences per sample.

3.9.3 Taxonomic Analysis

The processed sequences were grouped into Operational Taxonomic Units (OTU) using a classifier model trained on the UNITE version 8 (99%) reference database (https://unite.ut.ee/repository.php). The relative taxonomic abundance and count data in all ranks (Kingdom, Phylum, Class, Order, Family, Genus, and Species) were collected. The clustered heat map was generated at the Genus level.

3.9.4 Phylogenetic Tree Preparation and Diversity Analysis

The diversity of the samples was evaluated through both Alpha diversity and Beta diversity analyses of the OTUs. To count the features per sample, these diversity metrics necessitate a rooted phylogenetic tree that connects the various features.

To create the phylogenetic tree, the pipeline utilises the mafft program for multiple sequence alignment of the sequences, generating a Feature Data [Aligned Sequence] QIIME2 artifact. The alignment was then masked to eliminate highly variable positions, as they contribute noise to the resulting phylogenetic tree. Afterwards, the Fasttree program constructs the tree, using midpoint rooting to position the tree's root at the midpoint of the longest distance between tips in the unrooted tree. The resulting information will be recorded in a phylogeny [Rooted] QIIME2 artifact.

During the alpha diversity assessment, indices such as Chao, observed features, Shannon, and Simpson were calculated. Rarefaction curves and rank abundance curves were analysed to evaluate species richness and evenness within individual microbial communities of each sample. Additionally, beta diversity analysis was conducted to examine the similarity of community structures across different samples. Various beta diversity indices, including Unweighted and Weighted UniFrac distance matrices, Bray-Curtis distance matrix, and Jaccard distance matrix, were computed, and Multidimensional Scaling (MDS) analysis was carried out. In MDS, Principle Coordinate Analysis (PCoA) is the classical one that examines the similarities and dissimilarities between the samples (Ramette, 2007). The rank abundance curve was performed by QIIME1 software, and the rarefaction curve and beta diversity analysis were performed by QIIME2 Software.

Chapter 4

Results

4.1 Taxonomic Studies

Soil fungi were isolated from three sacred groves, located in three parts of Kerala, over three seasons spanning two years. A total of 168 species belonging to 34 genera were identified from these sacred groves. Ascomycota phylum constitutes over 94% of the total fungal species, making it the most abundant phylum, followed by Mucoromycota (6%). These phyla were classified into 6 classes, 8 subclasses, 12 orders, 19 families, and 34 genera. Additionally, 4 unknown species and 2 non-sporulating fungi were also discovered.

In this study, we utilise the fungal classification system proposed by Tedersoo et al. (2018) to categorise fungi and establish their systematic positions. Tedersoo et al. (2018) classified fungi into 18 different phyla: Ascomycota, Basidiomycota, Entorrhizomycota, Glomeromycota, Mortierellomycota, Mucoromycota, Clacarisporiellomycota, Entomophthoromycota, Kickxellomycota, Zoopagomycota, Basidiobolomycota, Olpidiomycota, Neocallimastigomycota, Monoblepharomycota, Chytridiomycota, Blastocladiomycota, Aphelidiomycota, and Rozellomycota. Fungal classification primarily depends on various characteristics, including colony morphology, features of the mycelium, structure of the fruiting bodies, and characteristics of spores or conidia. A checklist of the identified species is presented in Table 5. Additionally, taxa within each genus are organised in alphabetical order. The fungal taxa are arranged as follows:

Phylum - Ascomycota

Class - Dothideomycetes

Eurotiomycetes

Leotiomycetes

Saccharomycetes

Sordariomycetes

Phylum - Mucoromycota

Class - Mucoromycetes

Table 5. The checklist of taxa recorded from the study areas

Phylum	Class	Order	Family	Species
Ascomycota	Dothideomycetes	Cladosporiales	Cladosporiaceae	*Cladosporium cladosporioides*
		Pleosporales	Pleosporaceae	*Alternaria atra*
				Alternaria tenuissima
	Eurotiomycetes	Eurotiales	Aspergillaceae	*Aspergillus brevipes*
				Aspergillus caesiellus
				Aspergillus carneus
				Aspergillus conicus
				Aspergillus coremiiformis
				Aspergillus duricaulis
				Aspergillus flavus
				Aspergillus flavus var. *columnaris*
				Aspergillus flavus yellow mutant
				Aspergillus fumigatus
				Aspergillus kanagawaensis
				Aspergillus koningii
				Aspergillus niger
				Aspergillus ochraceus
				Aspergillus petrakii

	Aspergillus raperi
	Aspergillus subalbidus
	Aspergillus sulphureus
	Aspergillus viridinutans
	Aspergillus sp. 1
	Aspergillus sp. 2
	Aspergillus sp. 3
	Aspergillus sp. 4
	Aspergillus sp. 5
	Aspergillus sp. 6
	Aspergillus sp. 7
	Aspergillus sp. 8
	Aspergillus sp. 9
	Aspergillus sp. 10
	Aspergillus sp. 11
	Neosartorya quadricincta
	Paecilomyces stipitatus
	Paecilomyces victoriae
	Paecilomyces sp. 1
	Penicillium adametzii
	Penicillium aurantiogriseum var.

	aurantiogriseum
	Penicillium brevicompactum
	Penicillium capsulatum
	Penicillium chermesinum
	Penicillium chrysogenum
	Penicillium citrinum
	Penicillium crystallinum
	Penicillium cyaneum
	Penicillium granulatum
	Penicillium janczewskii
	Penicillium janthinellum
	Penicillium javanicum
	Penicillium lividum
	Penicillium miczynskii
	Penicillium novae-zeelandiae
	Penicillium paxilli
	Penicillium restrictum
	Penicillium roqueforti
	Penicillium roseopurpureum
	Penicillium simplicissimum
	Penicillium spinulosum

	Penicillium sublateritium
	Penicillium thomii var. *thomii*
	Penicillium velutinum
	Penicillium vinaceum
	Penicillium waksmanii
	Penicillium sp. 1
	Penicillium sp. 2
	Penicillium sp. 3
	Penicillium sp. 4
	Penicillium sp. 5
	Penicillium sp. 6
	Penicillium sp. 7
	Penicillium sp. 8
	Penicillium sp. 9
	Penicillium sp. 10
	Penicillium sp. 11
	Penicillium sp. 12
	Penicillium sp. 13
	Penicillium sp. 14
	Penicillium sp. 15
	Penicillium sp. 16

	Penicillium sp. 17
	Penicillium sp. 18
	Penicillium sp. 19
	Penicillium sp. 20
	Penicillium sp. 21
	Penicillium sp. 22
	Talaromyces aculeatus
	Talaromyces atroroseus
	Talaromyces brunneus
	Talaromyces diversus
	Talaromyces duclauxii
	Talaromyces flavus
	Talaromyces funiculosus
	Talaromyces islandicus
	Talaromyces piceae
	Talaromyces purpureogenus
	Talaromyces variabilis
	Talaromyces verruculosus
	Talaromyces sp. 1
	Talaromyces sp. 2
	Talaromyces sp. 3

				Talaromyces sp. 4
	Leotiomycetes	Helotiales	Myxotrichaceae	*Oidiodendron* sp. 1
	Saccharomycetes	Saccharomycetales	Dipodascaceae	*Geotrichum candidum*
	Sordariomycetes	Glomerellales	Glomerellaceae	*Colletotrichum aotearoa*
				Colletotrichum sp. 1
				Colletotrichum sp. 2
		Glomerellales	Plectosphaerellaceae	*Furcasterigmium furcatum*
				Plectosphaerella cucumerina
				Plectosphaerella sp. 1
		Hypocreales	Cordycipitaceae	*Cordyceps farinosa*
			Hypocreaceae	*Trichoderma asperelloides*
				Trichoderma hamatum
				Trichoderma harzianum
				Trichoderma spirale
				Trichoderma virens
				Trichoderma viride
				Trichoderma sp. 1
				Trichoderma sp. 2
				Trichoderma sp. 3
				Acremonium implicatum
				Acremonium sp. 1

		Acremonium sp. 2
		Acremonium sp. 3
		Acremonium sp. 4
		Gliomastix murorum
		Gliomastix roseogrisea
		Gliomastix sp. 1
		Sarocladium gamsii
		Sarocladium hominis
		Sarocladium kiliense
		Sarocladium sp. 1
	Nectriaceae	*Cosmospora butyri*
		Fusarium oxysporum
		Fusarium tricinctum
		Fusarium verticillioides
		Fusarium sp. 1
		Fusarium sp. 2
		Mariannaea sp. 1
		Neocosmospora solani
	Ophiocordycipitaceae	*Purpureocillium lilacinum*
		Purpureocillium lilacinum natural mutant

		Microascales	Microascaceae	*Cephalotrichum asperulum*
				Microascus atrogriseus
				Microascus sp. 1
				Scedosporium apiospermum
				Scedosporium sp. 1
				Scopulariopsis asperula
				Scopulariopsis brevicaulis
				Scopulariopsis candida
				Scopulariopsis sp. 1
				Wardomyces inflatus
		Chaetosphaeriales	Chaetosphaeriaceae	*Chloridium guttiferum*
				Chloridium sp. 1
				Chloridium sp. 2
		Diaporthales	Insertae sedis	*Sirococcus tsugae*
		Sordariales	Chaetomiaceae	*Trichocladium* sp. 1
				Trichocladium sp. 2
Mucoromycota	Mucoromycetes	Mucorales	Cunninghamellaceae	*Absidia cylindrospora*
				Gongronella butleri
				Gongronella sp. 1
				Gongronella sp. 2
			Lichtheimiaceae	*Rhizomucor pusillus*

		Mucoraceae	*Mucor bacilliformis*
			Mucor circinelloides
			Mucor hiemalis f. *corticola*
			Mucor hiemalis f. *hiemalis*
			Mucor mucedo
NSF			NSF 1
			NSF 2
Unknown			Unknown 1
			Unknown 2
			Unknown 3
			Unknown 4

4.1.1 Systematic Account

Phylum: Ascomycota
Class: Dothideomycetes
Order: Cladosporiales
Family: Cladosporiaceae
Genus: *Cladosporium* Link

1. ***Cladosporium cladosporioides*** (Fresen.) G.A. de Vries, in Domsch & Gams, Compendium of Soil Fungi, pp. 202, Fig. 82 (1980). **(Plate 01, A-C)**

Synonyms: *Penicillium cladosporioides* Fresen., Beiträge zur Mykologie 1: 22 (1850), *Hormodendrum cladosporioides* (Fresen.) Sacc., Michelia 2 (6): 148 (1880), *Monilia humicola* Oudem., Archives Néerlandaises 7: 286 (1902).

Description: Colonies ash to black, reverse black colour, cream colour margin; conidiophores solitary, erect, bearing conidial chains, 90–250 × 2–5 µm; conidia ellipsoidal, smooth-walled, ovate, 3–7 × 2–3 µm.

Distribution: Isolated from Poyilkavu.

Order: Pleosporales
Family: Pleosporaceae
Genus: *Alternaria* Nees

2. ***Alternaria atra*** (Preuss) Woudenb. & Crous, in Esfahani, Identification of *Ulocladium atrum* causing potato leaf blight in Iran, pp.2, Fig. 1 (2018). **(Plate 01, D-F)**

Synonyms: *Ulocladium atrum* Preuss, Linnaea 25: 75 (1852), *Stemphylium atrum* (Preuss) Sacc., Sylloge Fungorum 4: 520 (1886), *Alternaria abietis* Tengwall, Mededelingen Phytopathologisch Laboratorium "Willie Commelin Scholten" 6: 50 (1924), *Soredospora graminis* Corda, Icones fungorum hucusque cognitorum 1: 12, t. 3:173 (1837), *Stemphylium graminis* (Corda) Bonord., Handbuch der allgemeinen Mykologie: 83 (1851), *Fumago graminis* (Corda) S. Hughes, Canadian Journal of Botany 36 (6): 767 (1958).

Description: Colonies black with white margins, reverse black with cream colour margin; conidiophores simple or branched, erect; conidia solitary, spherical 2 to 4 celled, 15–27.5 x 24.1–24.7 µm.

Distribution: Isolated from Kollakal Thapovanam.

3. ***Alternaria tenuissima*** (Kunze) Wiltshire, in Domsch & Gams, Compendium of Soil Fungi, pp. 38, Fig. 17 (1980). **(Plate 01, G-I)**

Synonyms: *Helminthosporium tenuissimum* Kunze, Nova Acta Physico-Medica Academiae Caesareae Leopoldino-Carolinae Naturae Curiosorum 9 (1): 241, f. 12 (1818), *Clasterosporium tenuissimum* (Kunze) Sacc., Sylloge Fungorum 4: 393 (1886), *Macrosporium tenuissimum* (Kunze) Fr., Systema Mycologicum 3: 374 (1832),, *Alternaria rumicicola* R.L. Mathur, Agnihotri & Tyagi, Current Science 31 (7): 297 (1962), *Macrosporium amaranthi* Peck, Bulletin of the Torrey Botanical Club 22: 493 (1895), *Alternaria amaranthi* (Peck) J.M. Hook, Proc. Indiana Acad. Sci.: 214 (1921), *Macrosporium pruni-mahalebi* Săvul. & Sandu, Hedwigia 75: 228 (1935), *Macrosporium podophylli* Ellis & Everh., Proceedings of the Academy of Natural Sciences of Philadelphia 43: 92 (1891), *Alternaria podophylli* (Ellis & Everh.) P. Joly, Encyclopédie Mycologique 33: 212 (1964), *Macrosporium maydis* Cooke & Ellis, Grevillea 6 (39): 87 (1878), *Macrosporium martindalei* Ellis & G. Martin, The American Naturalist 18: 189 (1884), *Alternaria martindalei* (Ellis & G. Martin) P. Joly, Encyclopédie Mycologique 33: 209 (1964), *Alternaria amaranti* (Peck) J.M. Hook (1921).

Description: Colonies floccose, black in the middle with cream colour margin, reverse black colour, concentric rings present; conidiophores septate, 90.2–100 x 4.7–5 µm; conidia in short chains, obclavate, muriform with four to seven traverses, 25.5–38.7 x 7.4–8.6 µm.

Distribution: Isolated from Iringole Kavu.

Class: Eurotiomycetes

Order: Eurotiales

Family: Aspergillaceae

Genus: *Aspergillus* P. Micheli ex Haller

4. ***Aspergillus brevipes*** G. Sm., in Raper & Fennell, The Genus *Aspergillus*, pp. 251, Fig: 57 (1965). **(Plate 01, J-L)**

Synonyms: Nil.

Description: Colony bluish green with white margin, velvety, colourless exudates present, reverse yellow cream colour; conidial heads columnar; conidiophores

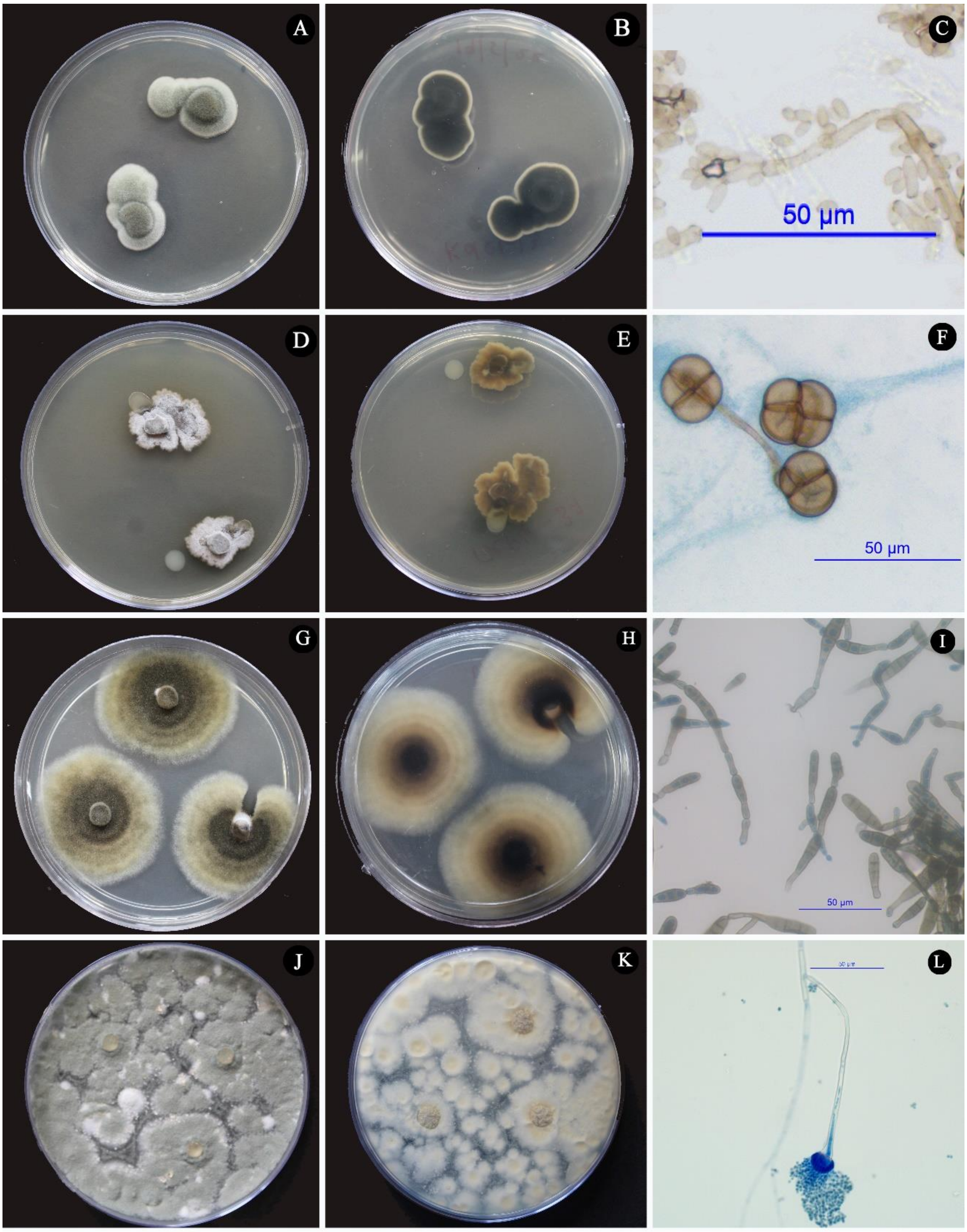

Plate 01. **A – C.** *Cladosporium cladosporioides.* **D – F.** *Alternaria atra*. **G – I.** *Alternaria tenuissima*. **J – L.** *Aspergillus brevipes.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, L.** Microscopic view with conidiophore and conidia; **I.** Microscopic view with conidia.

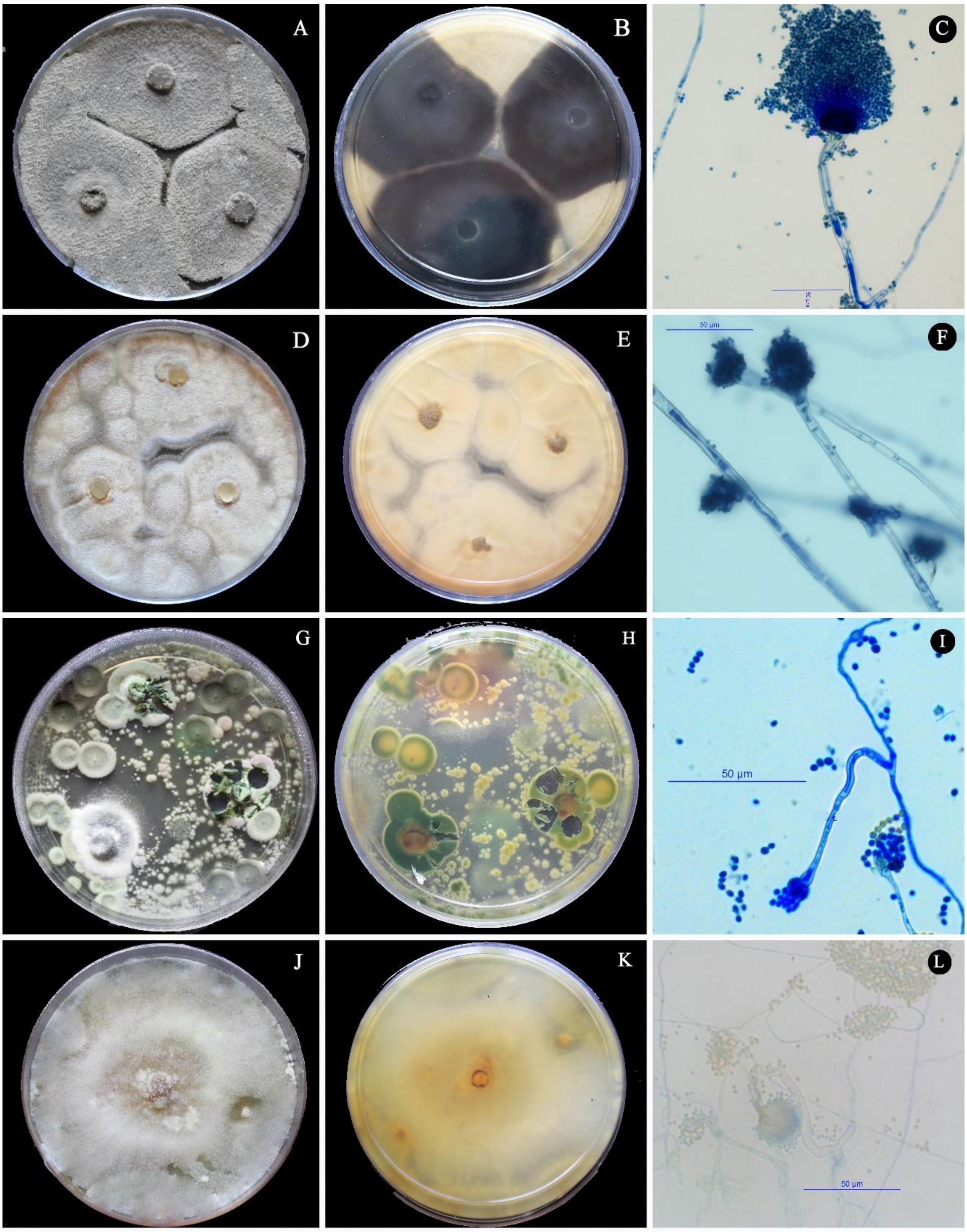

Plate 02. **A – C.** *Aspergillus caesiellus*. **D – F.** *Aspergillus carneus*. **G – I.** *Aspergillus conicus*. **J – L.** *Aspergillus coremiiformis*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

long, 60–147 x 4–5 µm; vesicles pear-shaped; sterigmata uniseriate; conidia globose, spinulose, 3–3.5 µm in diameter.

Distribution: Isolated from Iringole Kavu.

5. ***Aspergillus caesiellus*** Saito, in Raper & Fennell, The Genus *Aspergillus*, pp. 224, Fig: 52 (1965). **(Plate 02, A-C)**

   Synonyms: *Aspergillus gracilis* var. *sartoryi* Bat., O.G. Lima & A.F. Vital, Mycopathologia et Mycologia Applicata 8 (2): 96 (1957).

   Description: Colony storm grey colour, reverse dark green in the middle, then grey colour; conidial heads columnar; conidiophores smooth 80–100 x 4.2–6 µm; vesicles dome-shaped; sterigmata uniseriate; conidia elliptical, flattened on both ends, 4 x 2–3 µm.

   Distribution: Isolated from Iringole Kavu and Poyilkavu.

6. ***Aspergillus carneus*** (Tiegh.) Blochwitz, in Raper & Fennell, The Genus *Aspergillus*, pp. 564, Fig: 127 (1965). **(Plate 02, D-F)**

   Synonyms: *Sterigmatocystis carnea* Tiegh., Bulletin de la Société Botanique de France 24: 103 (1877).

   Description: Colony first white, becomes pale vinaceous fawn, reverse vinaceous fawn colour, colourless exudates present; conidial heads loosely columnar; conidiophores smooth, 198–300 x 5–7 µm; vesicles hemispherical; sterigmata biseriate; conidia subglobose, 2–2.5 µm in diameter.

   Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

7. ***Aspergillus conicus*** Blochwitz, in Raper & Fennell, The Genus *Aspergillus*, pp. 229, Fig: 54 (1965). **(Plate 02, G-I)**

   Synonyms: Nil.

   Description: Colony velvety, furrowed in central region, grey-green in colour, reverse dark yellow-green shades, colourless exudates present; conidial heads columnar; conidiophore short, 45–60 x 2.3–3.8 µm; vesicles small, as slight enlargements of conidiophore apices; sterigmata uniseriate; conidia elliptical, 3–4 x 3 µm in diameter.

   Distribution: Isolated from Iringole Kavu.

8. ***Aspergillus coremiiformis*** Bartoli & Maggi, in Bartoli & Maggi, Four new species of *Aspergillus* from Ivory Coast soil, pp. 386, Fig: 5–10 (1978). **(Plate 02, J-L)**

   Synonyms: Nil.

Description: Colony floccose, first white then lemon chrome in colour, reverse cream colour; conidial heads radial; conidiophore simple, 55–200 x 25–30 µm; vesicles subglobose, fertile over entire surface; sterigmata biseriate; conidia oval, 2.5–3 x 3–5 µm.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

9. ***Aspergillus duricaulis*** Raper & Fennell, in Raper & Fennell, The Genus *Aspergillus*, pp. 249, Fig: 57 (1965). **(Plate 03, A-C)**

Synonyms: Nil.

Description: Colony velvety, slate olive in colour, reverse cream colour; conidial heads loosely columnar; conidiophore uniformly thick, 62 x 4 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, echinulate, 3–3.2 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

10. ***Aspergillus flavus*** Link, in Raper & Fennell, The Genus *Aspergillus*, pp. 361, Fig: 75 (1965). **(Plate 03, D-F)**

Synonyms: *Aspergillus flavus* var. *flavus, Monilia flava* (Link) Pers., Mycologia Europaea 1: 30 (1822), *Aspergillus flavus* subsp. *flavus, Aspergillus flavus* f. *flavus, Aspergillus flavus* var. *proliferans* Anguli, Rajam, Thirum., Rangiah & Ramamurthi, Indian Journal of Microbiology: 94 (1965), *Sterigmatocystis lutea* Tiegh., Bulletin de la Société Botanique de France 24: 103 (1877), *Aspergillus luteus* (Tiegh.) C.W. Dodge, Medical mycology. Fungous diseases of men and other mammals: 625 (1935).

Description: Colony first white, becomes deep grape in colour, reverse reddish-brown colour, black colour sclerotia covered with exudates present, slate olive in colour, reverse cream colour; conidial heads radiate to loosely columnar; conidiophore simple, 150–200 x 3–5 µm; vesicles elongate; sterigmata uniseriate; conidia globose, echinulate, 3–4 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

11. ***Aspergillus flavus* var. *columnaris*** Raper & Fennell, in Raper & Fennell, The Genus *Aspergillus*, pp. 366, Fig: 75 (1965). **(Plate 03, G-I)**

Synonyms: *Aspergillus flavus* var. *asper* Y. Sasaki, Journal of the Faculty of Agriculture of the Hokkaido Imperial University 49: 143 (1950).

Description: Colony velvety, in bright yellow-green colour, reverse cream colour; conidial heads columnar; conidiophore simple, uniformly thickened, 160–200 x 4–

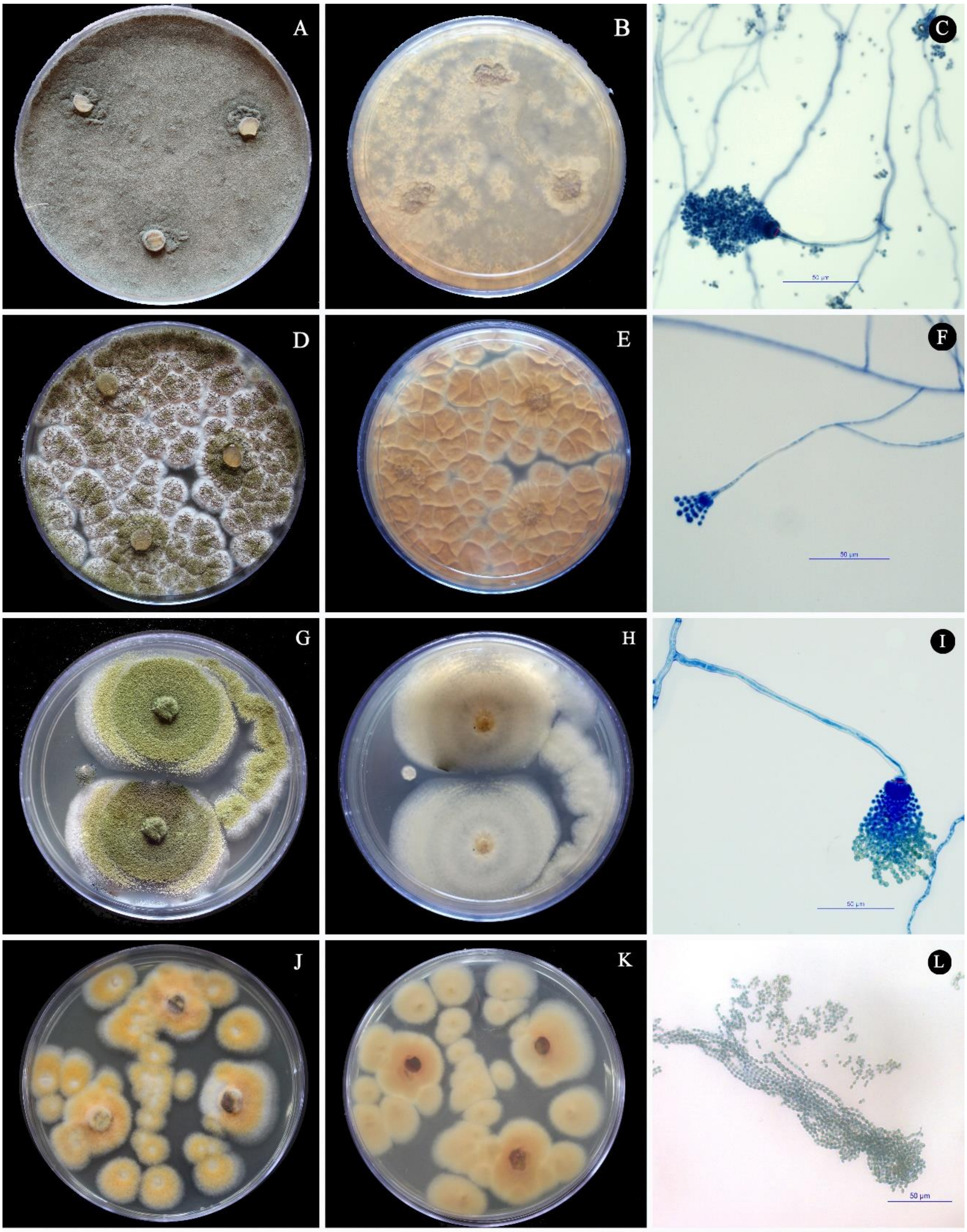

Plate 03. **A – C.** *Aspergillus duricaulis*. **D – F.** *Aspergillus flavus*. **G – I.** *Aspergillus flavus* var. *columnaris*. **J – L.** *Aspergillus flavus* yellow mutant. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I.** Microscopic view with conidiophore and conidia; **L.** Microscopic view with conidia.

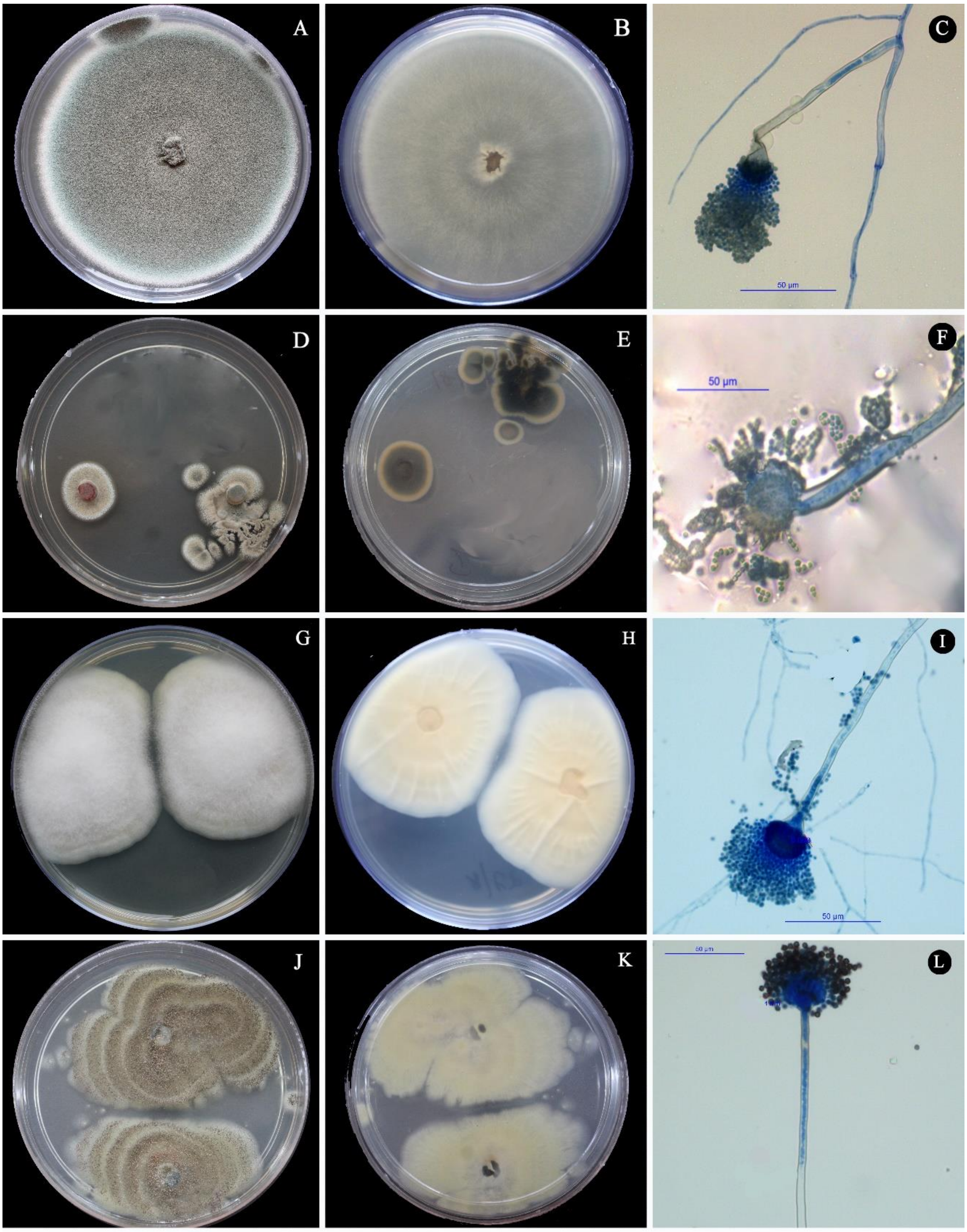

Plate 04. **A – C.** *Aspergillus fumigatus.* **D – F.** *Aspergillus kanagawaensis*. **G – I.** *Aspergillus koningii*. **J – L.** *Aspergillus niger.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

5 µm; vesicles subglobose; sterigmata uniseriate; conidia globose, echinulate, 3–4 µm in diameter.

Distribution: Isolated from Iringole Kavu.

12. ***Aspergillus flavus* Yellow Mutant,** in Chang et al., Identification of a copper-transporting ATPase involved in biosynthesis of *A. flavus* conidial pigment, pp. 4891, Fig: 1 (2019). **(Plate 03, J-L)**

Synonyms: Nil.

Description: Colony velvety, first white then in bright yellow colour, reverse light-yellow colour; conidial heads radiate to loosely columnar; conidiophore simple, 150–200 x 3–5 µm; vesicles elongate; sterigmata uniseriate; conidia globose, echinulate, 3–4 µm in diameter.

Distribution: Isolated from Iringole Kavu.

13. ***Aspergillus fumigatus*** Fresen., in Raper & Fennell, The Genus *Aspergillus*, pp. 242, Fig: 55 (1965). **(Plate 04, A-C)**

Synonyms: *Aspergillus fumigatus* var. *fumigatus* (1863), *Aspergillus fumigatus* var. *acolumnaris* Rai, Agarwal & Tewari, (1971), *Aspergillus fumigatus* var. *ellipticus* Raper & Fennell (1965), *Aspergillus phialiseptatus* Kwon-Chung (1975), *Aspergillus anomalus* Mosseray (1934), *Aspergillus cellulosae* Hopffe, *Aspergillus septatus* Sartory & Sartory (1943), *Aspergillus pidoplichknovii* Bilai & Koval (1988), *Aspergillus fumigatus* var. *lunzinense* Szilvinyi (1941), *Aspergillus fumigatus* var. *griseibrunneus* Rai & Singh (1974), *Aspergillus fumigatus* var. *albus* Rai, Tewari & Agarwal (1974), *Aspergillus bronchialis* Blumentritt (1901), *Aspergillus fumigatus* var. *cellulosae* Sartory, Sartory & Mey (1935), *Aspergillus fumigatus* var. *helvolus* Yuill (1937), *Aspergillus fumigatus* var. *minimus* Sartory (1919), *Aspergillus phialiseptus* Kwon-Chung (1975).

Description: Colony velvety, first white then in lily green colour, reverse transparent; conidial heads columnar; conidiophore short, 85–100 x 5–7.5 µm; vesicles fertile on upper half; sterigmata uniseriate; conidia globose, echinulate, 2–3 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

14. ***Aspergillus kanagawaensis*** Nehira, in Raper & Fennell, The Genus *Aspergillus*, pp. 217, Fig: 51 (1965). **(Plate 04, D-F)**

Synonyms: Nil.

Description: Colony velvety, avellaneous shade, reverse brown-green shade; conidial heads loosely radiate; conidiophore erect, 230–345 x 3.4–6.8 µm; vesicles globose; sterigmata uniseriate; conidia globose, 3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

15. ***Aspergillus koningii*** Oudem., in Gilman, A Manual of Soil Fungi, pp. 232 (1956). **(Plate 04, G-I)**

Synonyms: Nil.

Description: Colony cottony, white in colour, sulcations present, reverse cream colour, striations present; conidial heads radiate; conidiophore smooth, non-septate 156–205 x 5–6 µm; vesicles globose; sterigmata uniseriate; conidia globose, 3 µm in diameter.

Distribution: Isolated from Poyilkavu.

16. ***Aspergillus niger*** Tiegh., in Raper & Fennell, The Genus *Aspergillus*, pp. 309, Fig: 67–68 (1965). **(Plate 04, J-L)**

Synonyms: *Sterigmatocystis nigra* (Tiegh.) Tiegh., Bulletin de la Société Botanique de France 24: 102 (1877), *Aspergillopsis nigra* (Tiegh.) Speg., Anales del Museo Nacional de Historia Natural Buenos Aires ser. 3, 13: 435 (1911), *Rhopalocystis nigra* (Tiegh.) Grove: 41 (1911), *Eurotium nigrum* (Tiegh.) de Bary, Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft 7: 381 (1870), *Aspergillus foetidus* Thom & Raper, A manual of the Aspergilli: 219 (1945), *Aspergillus foetidus* var. *foetidus*, *Aspergillus hennebergii* Blochwitz, Annales Mycologici 33 (3–4): 238 (1935), *Aspergillus pseudocitricus* Mosseray, La Cellule 43: 228–229 (1934), *Aspergillus usamii* Sakag., Iizuka & M. Yamaz. ex Iizuka & K. Sugiy., J. Agric. Chem. Soc. Japan: 232 (1960), *Aspergillus niger* var. *usamii* (Sakag., Iizuka & M. Yamaz. ex Iizuka & K. Sugiy.) Al-Musallam, Revision of the black *Aspergillus* species: 64 (1980), *Aspergillus usamii* var. *usamii*, *Aspergillus batatas* Saito, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 18: 34 (1907), *Sterigmatocystis batatas* (Saito) Sacc., Sylloge Fungorum 22: 1261 (1913), *Aspergillus batatae* Saito (1907), *Aspergillus fuliginosus* Peck, Bulletin of the Buffalo Society of Natural Sciences 1: 69 (1873), *Aspergillus longobasidia* Bainier, La Cellule 43: 227 (1934), *Aspergillus pyri* W.H. English (1940), *Aspergillus niger* var. *altipes* E. Schiemann, Mutationen bei *Aspergillus niger* v. *Tieghem*, Inaugural-Diss (1912), *Aspergillus niger* f.

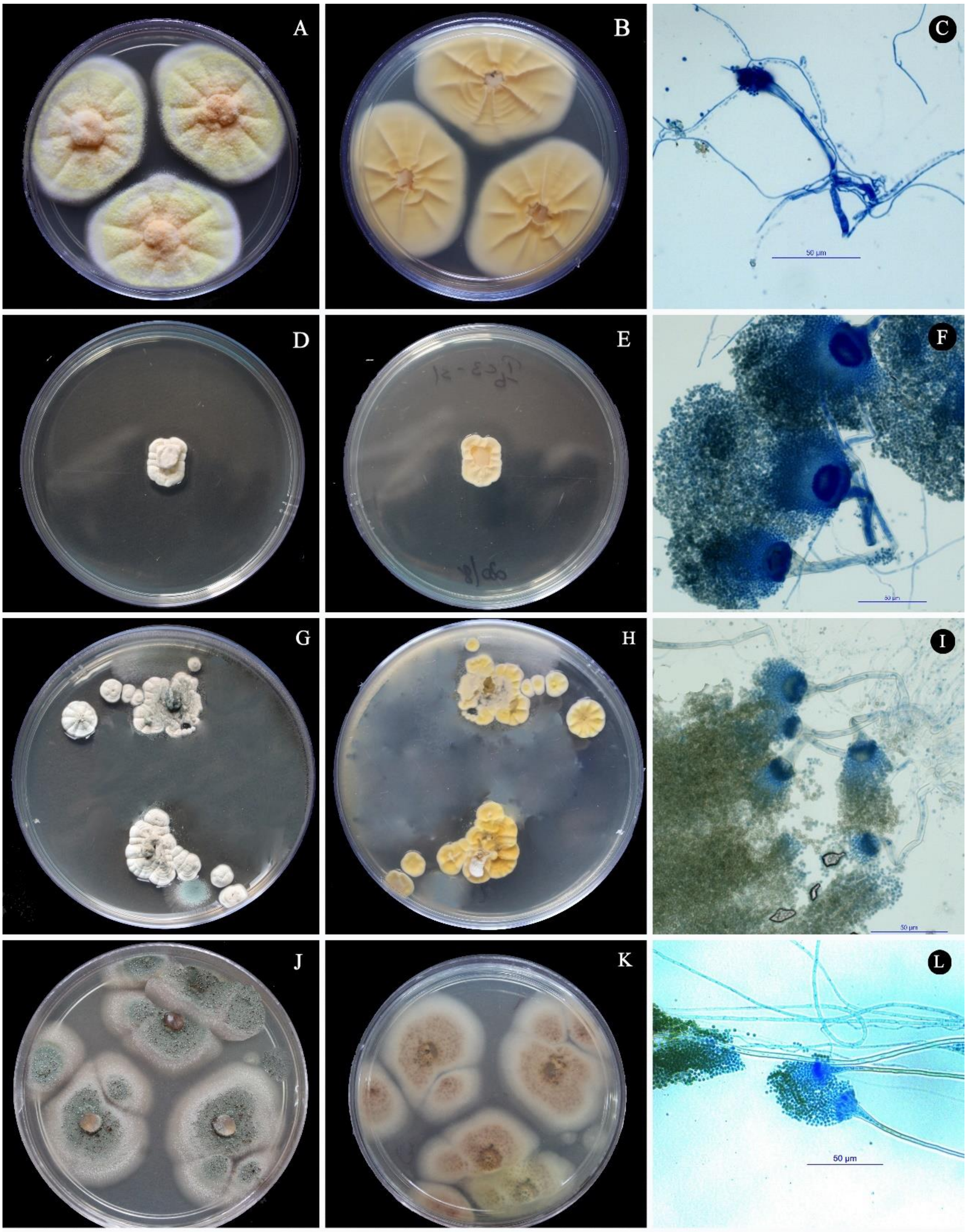

Plate 05. **A – C.** *Aspergillus ochraceus.* **D – F.** *Aspergillus petrakii*. **G – I.** *Aspergillus raperi*. **J – L.** *Aspergillus subalbidus.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

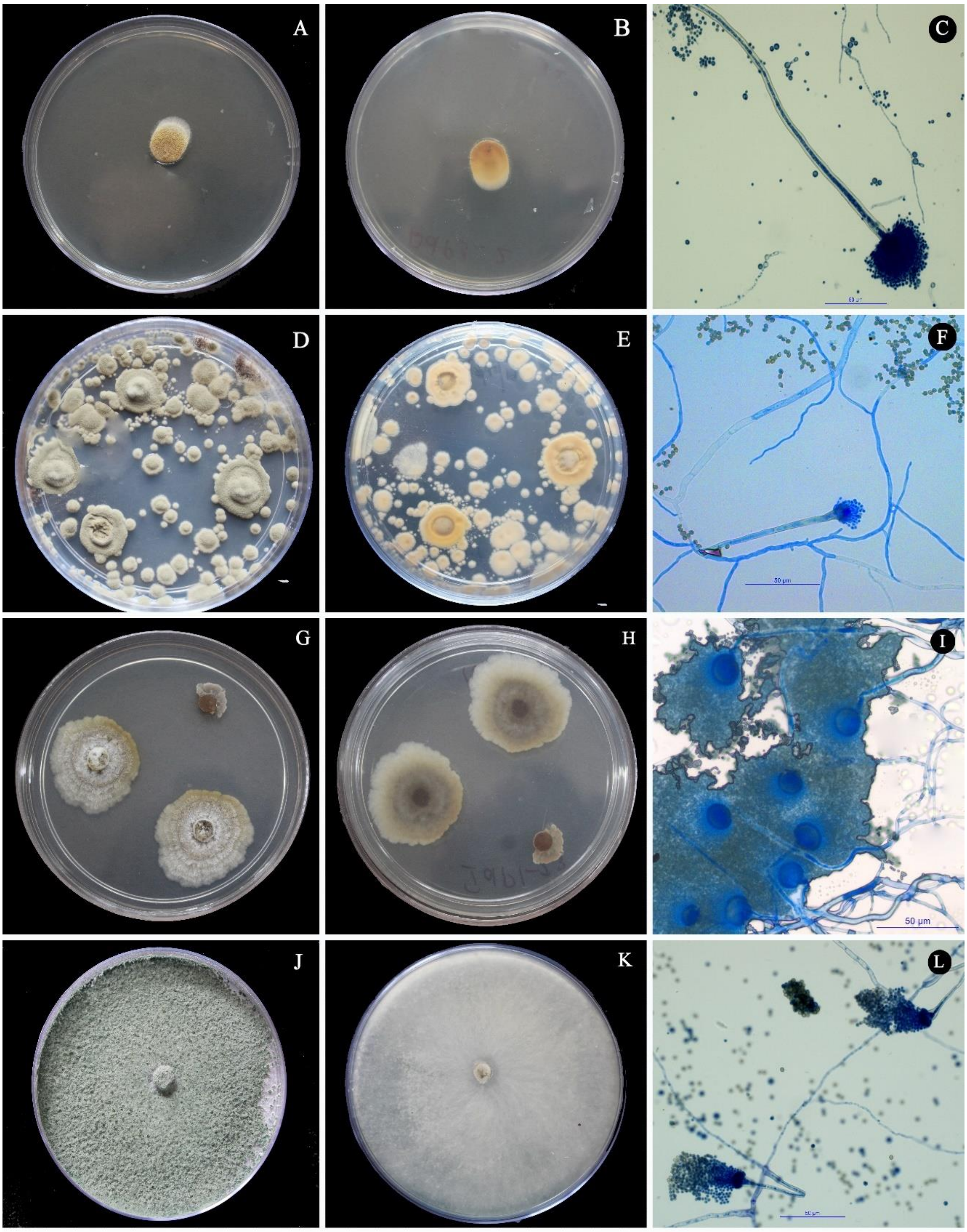

Plate 06. **A – C.** *Aspergillus sulphureus*. **D – F.** *Aspergillus viridinutans*. **G – I.** *Aspergillus* sp. 1. **J – L.** *Aspergillus* sp. 2. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

hennebergii Blochwitz ex Al-Musallam, Revision of the black Aspergillus species: 68 (1980), *Aspergillus lacticoffeatus* Frisvad & Samson, Stud. Mycol. 50 (1): 52 (2004), *Aspergillus citricus* Mosseray (1934), *Aspergillus citricus* var. *citricus*, *Ustilago welwitschiae* Bres., Boletim da Sociedade Broteriana 11: 68 (1893), *Aspergillus welwitschiae* (Bres.) Henn. (1907), *Sterigmatocystis welwitschiae* (Bres.) Henn. (1903), *Ustilago ficuum* Reichardt, Verhandlungen der Zoologisch-Botanischen Gesellschaft Wien 17: 335 (1867), *Aspergillus ficuum* (Reichardt) Thom & Currie, J. Agric. Res. 7: 12 (1916), *Sterigmatocystis ficuum* (Reichardt) Henn., Hedwigia 34: 86 (1895), *Aspergillus niger* var. *ficuum* (Reichardt) Kozak., Mycological Papers 161: 112 (1989), *Aspergillus aureum* var. *brevis* Nakaz., Simo & A. Watan. (1936), *Sterigmatocystis batatae* (Saito) Sacc. (1913), *Aspergillus aureus* var. *brevior* Nakaz., Simo & A. Watan. (1936), *Aspergillus vinaceus* Ferranti, Iamanaka, Frisvad, O. Puel & J.J. da Silva, J. Fungi 6 (no. 371): 14 (2020).

Description: Colony white in colour, with brownish-black conidial structures, concentric rings present, reverse pale-yellow colour; conidial heads large, radiate; conidiophores smooth, 2–3 mm x 3–4 µm; vesicles globose; sterigmata biseriate; conidia globose, echinulate, 4–5 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

17. ***Aspergillus ochraceus*** K. Wilh., in Raper & Fennell, The Genus *Aspergillus*, pp. 281, Fig: 65 (1965). (**Plate 05, A-C)**

Synonyms: *Aspergillus ochraceus* var. *microsporus* Tirab., Annali Bot.: 14 (1908), *Sterigmatocystis japonica* K. Aoki, Bull. seric. Exp. Stn. Japan 11 (1): 20 (1942), *Aspergillus alutaceus* Berk. & M.A. Curtis, Grevillea 3 (27): 108 (1875).

Description: Colony ochraceous buff in colour, sulcations present, red colour exudates present in the middle region, reverse yellow shade; conidial heads columnar; conidiophore thick, 800–1000 x 4–6 µm; vesicles globose; sterigmata biseriate; conidia globose, 3 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

18. ***Aspergillus petrakii*** Vörös-Felkai, in Raper & Fennell, The Genus *Aspergillus*, pp. 287 (1965). (**Plate 05, D-F)**

Synonyms: *Aspergillus quercinus* var. *petrakii* (Vörös-Felkai) Kozak., Mycological Papers 161: 124 (1989).

Description: Colony white colour, sulcations present, colourless exudates present, reverse cream colour; conidial heads globose, loosely radiate; conidiophore thick, 142–300 x 6–9 µm; vesicles subglobose; sterigmata biseriate; conidia globose, 2–3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

19. ***Aspergillus raperi*** Stolk & J.A. Mey., in Raper & Fennell, The Genus *Aspergillus*, pp. 209, Fig: 48 (1965). **(Plate 05, G-I)**

Synonyms: Nil.

Description: Colony first white, then in sage green colour, concentric rings present, reverse primuline yellow colour; conidial heads radiate; conidiophore smooth, thick, 150–600 x 6–10 µm; vesicles elongate to subglobose; sterigmata uniseriate; conidia elliptical, 3–4 x 2.2–3 µm.

Distribution: Isolated from Iringole Kavu.

20. ***Aspergillus subalbidus*** Visagie, Hirooka & Samson, in Visagie et al., *Aspergillus*, *Penicillium* and *Talaromyces* isolated from house dust samples collected around the world, pp. 101, Fig: 31 (2014). **(Plate 05, J-L)**

Synonyms: Nil.

Description: Colony floccose, first white colour, then in ash green shade, black sclerotia present, reverse brown colour; conidial heads globose; conidiophores smooth, 200–300 x 2.5–3.2 µm; vesicles globose; sterigmata biseriate; conidia globose, 2.5–4 µm in diameter.

Distribution: Isolated from Iringole Kavu.

21. ***Aspergillus sulphureus*** (Fresen.) Wehmer, in Raper & Fennell, The Genus *Aspergillus*, pp. 271 (1965). **(Plate 06, A-C)**

Synonyms: *Sterigmatocystis sulphurea* Fresen., Beiträge zur Mykologie 3: 83 (1863), *Aspergillus fresenii* Subram., Hyphomycetes: an account of Indian species, except Cercosporae: 552 (1971).

Description: Colony granular, first white colour, sclerotia present in Naples yellow colour, reverse yellow shade; conidial heads loosely radiate; conidiophores smooth, 526–556 x 6–7 µm; vesicles globose; sterigmata biseriate; conidia globose, 2 µm in diameter.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

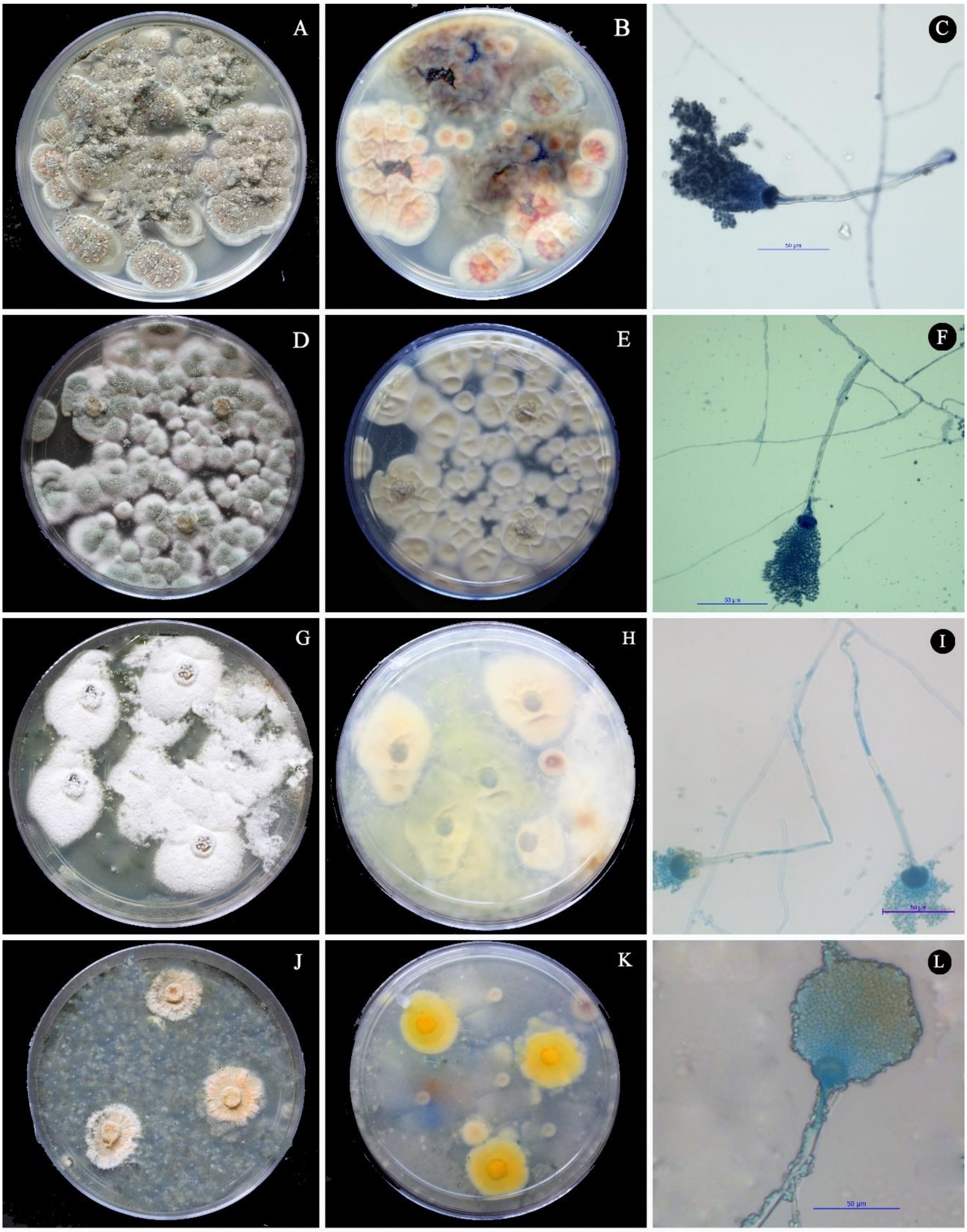

Plate 07. A – C. *Aspergillus* sp. 3. **D – F.** *Aspergillus* sp. 4. **G – I.** *Aspergillus* sp. 5. **J – L.** *Aspergillus* sp. 6. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

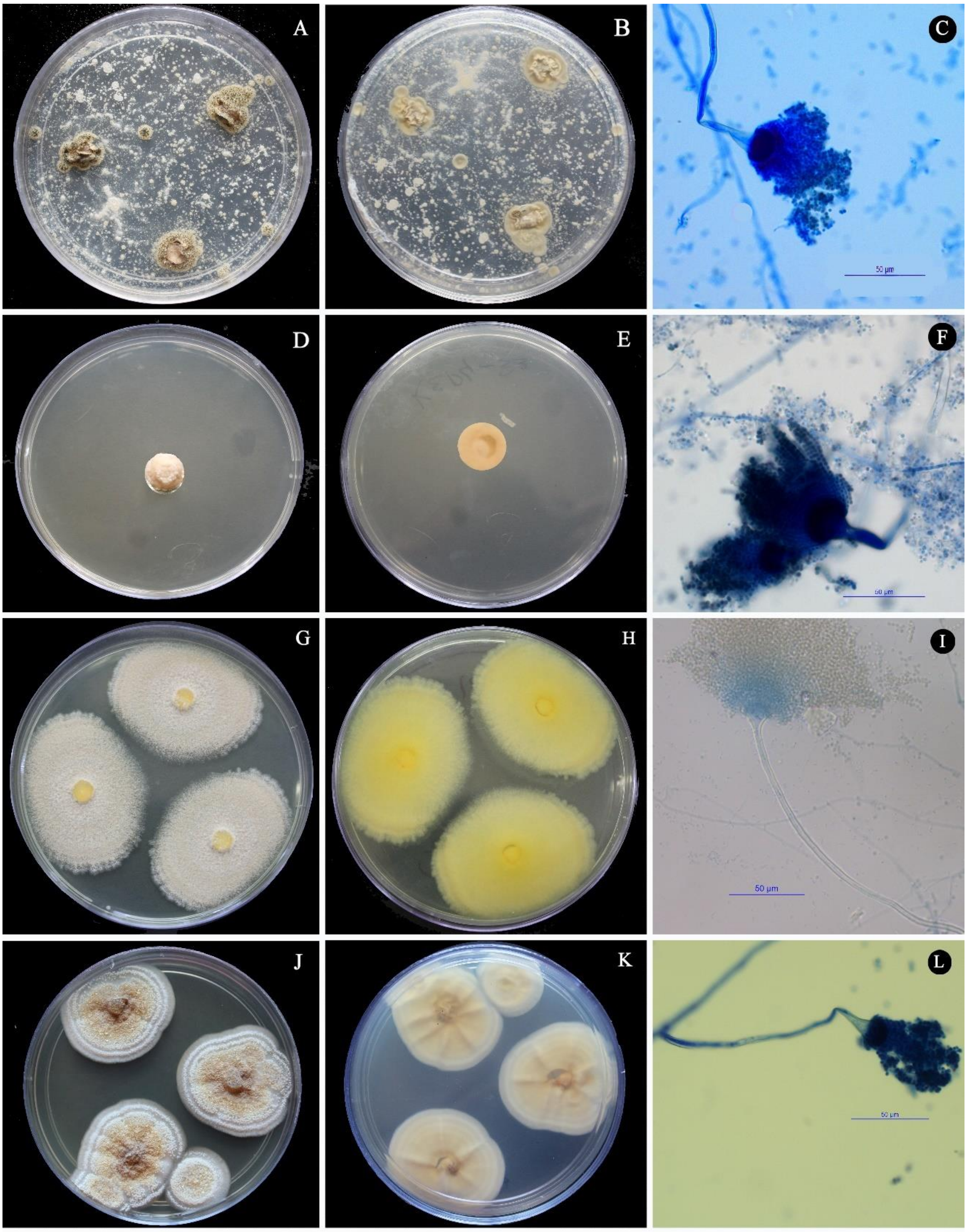

Plate 08. **A – C.** *Aspergillus* sp. 7. **D – F.** *Aspergillus* sp. 8. **G – I.** *Aspergillus* sp. 9. **J – L.** *Aspergillus* sp. 10. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

22. ***Aspergillus viridinutans*** Ducker & Thrower, in Raper & Fennell, The Genus *Aspergillus*, pp. 247, Fig; 56 (1965). **(Plate 06, D-E)**

Synonyms: Nil.

Description: Colony centre raised, first white colour, then in sage green colour, colourless exudates present, reverse orange shade; conidial heads columnar; conidiophores septate, 80–92.2 x 3.5–3.9 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, 2.16–2.5 µm in diameter.

Distribution: Isolated from Iringole Kavu.

23. ***Aspergillus* sp. 1** **(Plate 06, G-I)**

Synonyms: Nil.

Description: Colony floccose, first white colour, then brown colour, reverse brownish-black shade with white colour margin; conidial heads radiate; conidiophores septate, 56–98 x 3–3.5 µm; vesicles globose; sterigmata uniseriate; conidia globose, 1–2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

24. ***Aspergillus* sp. 2** **(Plate 06, J-L)**

Synonyms: Nil.

Description: Colony floccose, first in white colour, then in grey-green colour, reverse transparent; conidial heads columnar; conidiophores simple, 82–102 x 3.5–4 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, 3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

25. ***Aspergillus* sp. 3** **(Plate 07, A-C)**

Synonyms: Nil.

Description: Colony cottony, centre raised, ash colour, white colour margin, concentric rings present, reverse red colour; conidial heads columnar; conidiophores simple, 73–135 x 4–6 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, echinulate, 1.5–2 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

26. ***Aspergillus* sp. 4** **(Plate 07, D-F)**

Synonyms: Nil.

Description: Colony puffy, in bluish green colour, white colour margin, colourless exudates present, reverse furrowed, light-yellow shade; conidial heads columnar;

conidiophores simple, 111–182 x 3 µm; vesicles elongate; sterigmata uniseriate; conidia globose, 1–2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

27. ***Aspergillus* sp. 5** **(Plate 07, G-I)**

Synonyms: Nil.

Description: Colony granular, in white colour, colourless exudates present, reverse cream colour, striations present; conidial heads radiate; conidiophores simple, 138–195 x 4.5–6 µm; vesicles elongate to subglobular; sterigmata uniseriate; conidia globose, 1.8–2.2 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

28. ***Aspergillus* sp. 6** **(Plate 07, J-L)**

Synonyms: Nil.

Description: Colony floccose, orange in colour, white margin, reverse bright yellow colour; conidial heads loosely columnar; conidiophores large, 200–300 x 3.2–4.3 µm; vesicles globular; sterigmata uniseriate; conidia globose, 1.5–2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

29. ***Aspergillus* sp. 7** **(Plate 08, A-C)**

Synonyms: Nil.

Description: Colony thick, orange to ash green in colour, white margin, reverse cream colour, sulcations present; conidial heads radiate; conidiophores large, thick, 300–500 x 9–12 µm; vesicles globular; sterigmata biseriate; conidia oval, 4–5 x 3–4 µm.

Distribution: Isolated from Iringole Kavu.

30. ***Aspergillus* sp. 8** **(Plate 08, D-F)**

Synonyms: Nil.

Description: Colony wet, cream in colour, sulcations present, reverse orange shade; conidial heads radiate; conidiophores thick, 116–204 x 7–10 µm; vesicles globular; sterigmata uniseriate; conidia globose, 2–3 µm in diameter.

Distribution: Isolated from Poyilkavu.

31. ***Aspergillus* sp. 9** **(Plate 08, G-I)**

Synonyms: Nil.

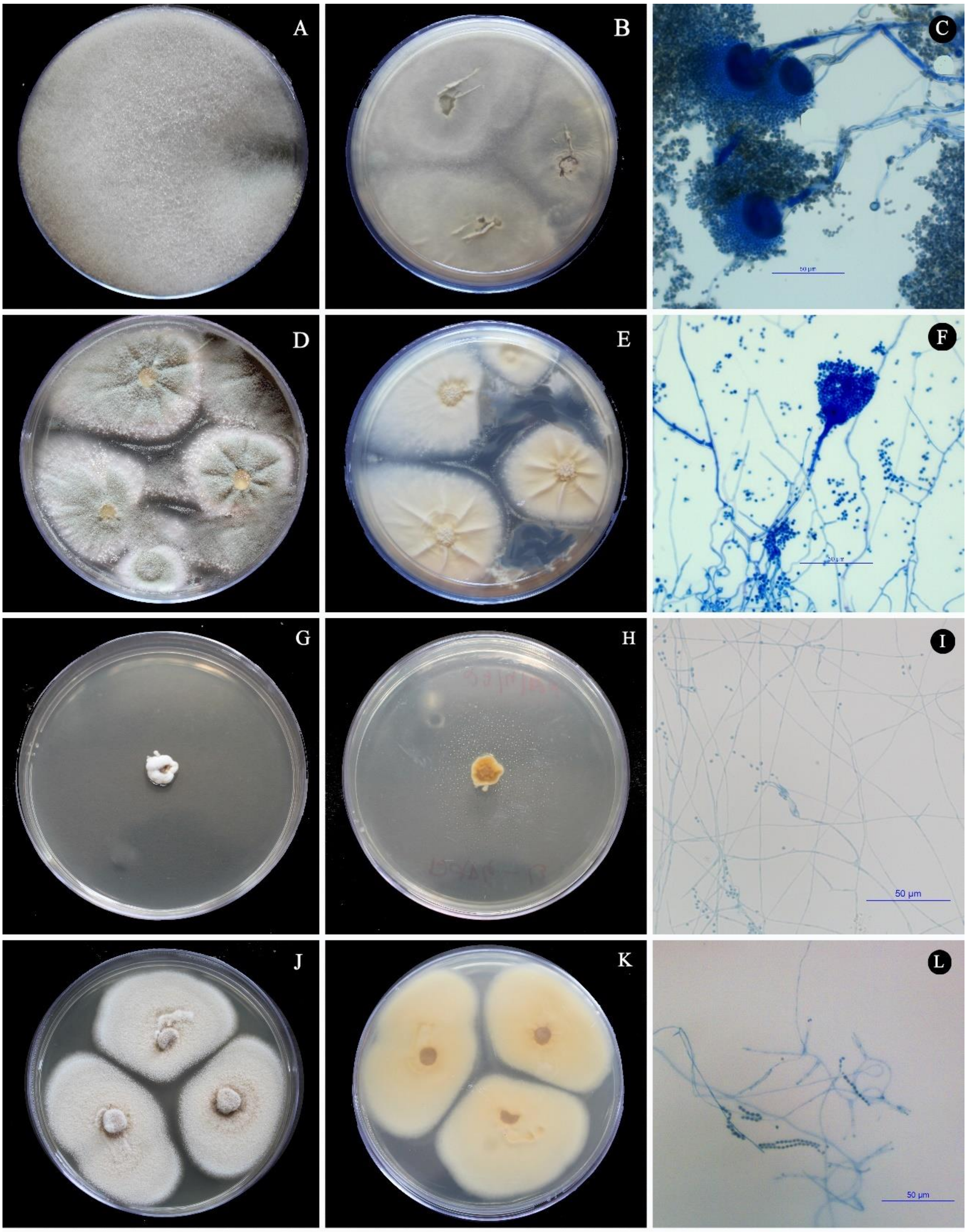

Plate 09. **A – C.** *Aspergillus* sp. 11. **D – F.** *Neosartorya quadricincta*. **G – I.** *Paecilomyces stipitatus*. **J – L.** *Paecilomyces victoriae*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, l.** Microscopic view with conidiophore and conidia.

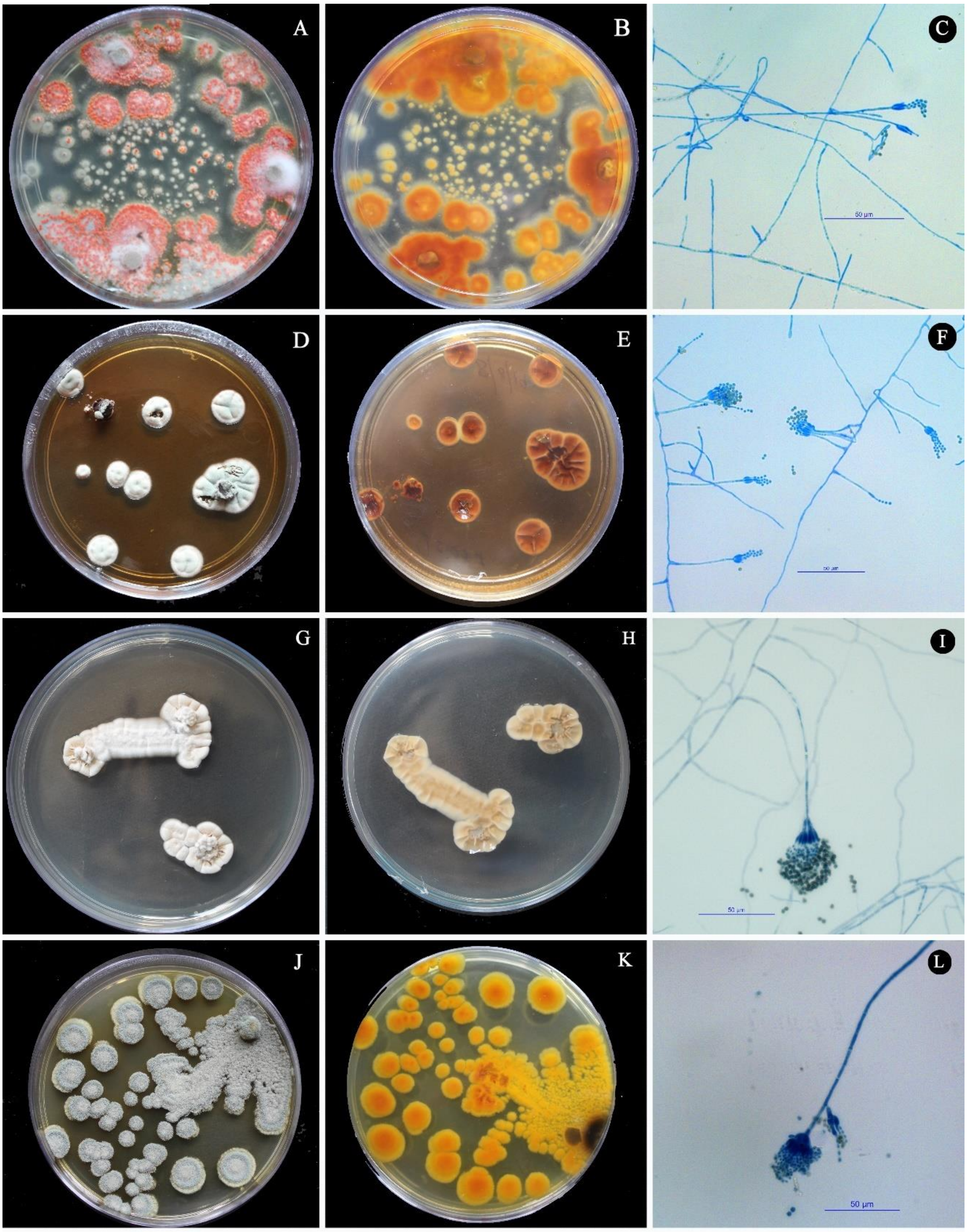

Plate 10. **A – C.** *Paecilomyces* sp. 1. **D – F.** *Penicillium adametzii*. **G – I.** *Penicillium aurantiogriseum* var. *aurantiogriseum* **J – L.** *Penicillium brevicompactum.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Description: Colony velvety, cream in colour, colourless glittering exudates present, PDA colour changes to yellow, reverse bright yellow colour; conidial heads columnar; conidiophores smooth, 67–207 x 2.9–4.4 µm; vesicles hemispherical; sterigmata biseriate; conidia globose, 1.5–2.1 µm in diameter.

Distribution: Isolated from Iringole Kavu.

32. ***Aspergillus* sp. 10** **(Plate 08, J-L)**

Synonyms: Nil.

Description: Colony granular, in white colour, then orange-pink-yellow shades, colourless exudates present, sulcations present, reverse orange-yellow shade; conidial heads columnar; conidiophores smooth, 115–130 x 4–5 µm; vesicles elongate; sterigmata uniseriate; conidia globose, 3 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

33. ***Aspergillus* sp. 11** **(Plate 09, A-C)**

Synonyms: Nil.

Description: Colony cottony, first in white colour, then grey colour, reverse grey shade; conidial heads radiate; conidiophores thick, 160–202 x 8–11 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, small, 1–2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

Genus: ***Neosartorya*** **Malloch & Cain**

34. ***Neosartorya quadricincta*** (E. Yuill) Malloch & Cain**,** in Raper & Fennell, The Genus Aspergillus, pp. 257, Fig: 59 (1965). **(Plate 09, D-F)**

Synonyms: *Aspergillus quadricinctus* E. Yuill, Transactions of the British Mycological Society 36 (1): 57 (1953), *Sartorya quadricincta* (E. Yuill) Udagawa & H. Kawas., Trans. Mycol. Soc. Japan: 119 (1968).

Description: Colony floccose, furrowed, first in white colour, then in tea green colour, colourless exudates present, reverse yellow shade, striations present; conidial heads columnar; conidiophores smooth, 92–150 x 4–6 µm; vesicles flask-shaped; sterigmata uniseriate; conidia globose, small, 2 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

Genus: ***Paecilomyces*** **Bainier**

35. ***Paecilomyces stipitatus*** Z.Q. Liang & Y.F. Han, in Liang et al., Studies on the genus *Paecilomyces* in China. I, pp. 95 (2005). **(Plate 09, G-I)**

Synonyms: Nil.

Description: Colony in white colour, reverse yellow-orange shade; conidiophores either directly bear conidiogenous cells or branches with whorls of 2 to 5 phialides; phialides have stalk, then cylindrical portion, then thin neck, 11–20.7 x 1.4–2.5 µm; conidia one-celled, ellipsoidal or fusiform, 2–2.7 x 1.4–2.7 µm.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

36. ***Paecilomyces victoriae*** (Szilvinyi) A.H.S. Br. & G. Sm., in Watanabe*,* Pictorial atlas of soil and seed fungi, pp. 199, Fig: DP3 (2010). **(Plate 09, J-L)**

Synonyms: Nil.

Description: Colony velvety, in white colour with brown tint, reverse orange shade; conidiophores erect, branched apically; phialides opposite, cylindrical base, pointed neck, apical phialides bear conidia, 12.3–16.7 x 1.8–2.5 µm; conidia one-celled, broadly ellipsoidal, 2.4–3 µm.

Distribution: Isolated from Kollakal Thapovanam.

37. ***Paecilomyces* sp.1** **(Plate 10, A-C)**

Synonyms: Nil.

Description: Colony granular, in orange-red colour, reverse orange to red colour; conidiophores erect, branches with apical whorls of phialides; phialides cylindrical base, pointed neck, 7.6–10.6 x 1.7–2.8 µm; conidia one-celled, ellipsoidal, 2.6–2.8 × 1.6–1.8 µm.

Distribution: Isolated from Poyilkavu.

Genus: *Penicillium* Link

38. ***Penicillium adametzii*** K. Zaleski, in Raper & Thom, A Manual of the Penicillia, pp. 228, Fig: 62 (1949). **(Plate 10, D-F)**

Synonyms: Nil.

Description: Colony tough, in tea green colour, white colour margin, radially wrinkled, PDA colour changes to brown, reverse dark brown colour; conidiophores short perpendicular branches, 26.7–41.4 x 1.5–1.7 µm; penicilli monoverticillata; conidia as tangled chains, granular, subglobose, 1.5–2.3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

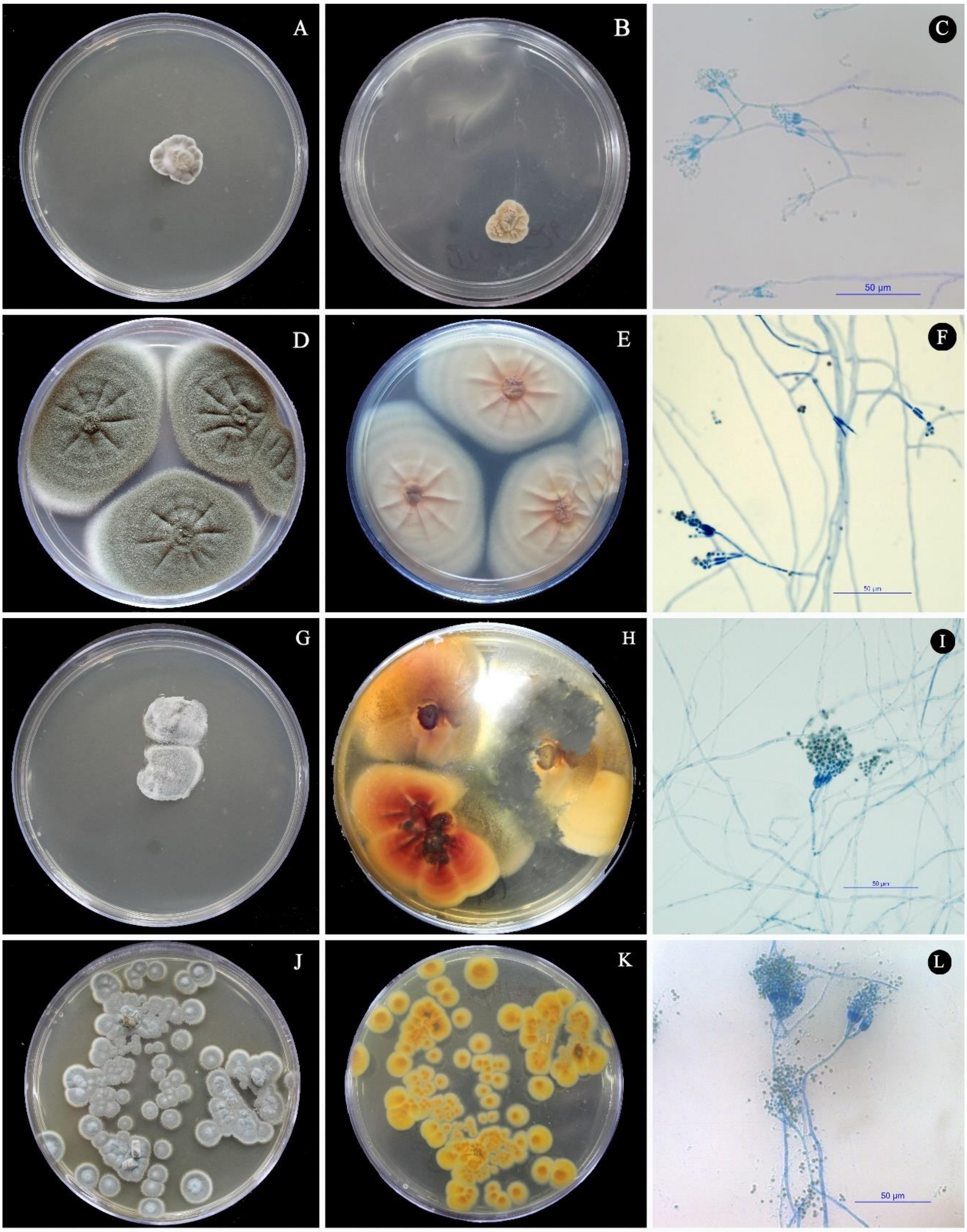

Plate 11. **A – C.** *Penicillium capsulatum*. **D – F.** *Penicillium chermesinum*. **G – I.** *Penicillium chrysogenum*. **J – L.** *Penicillium citrinum*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

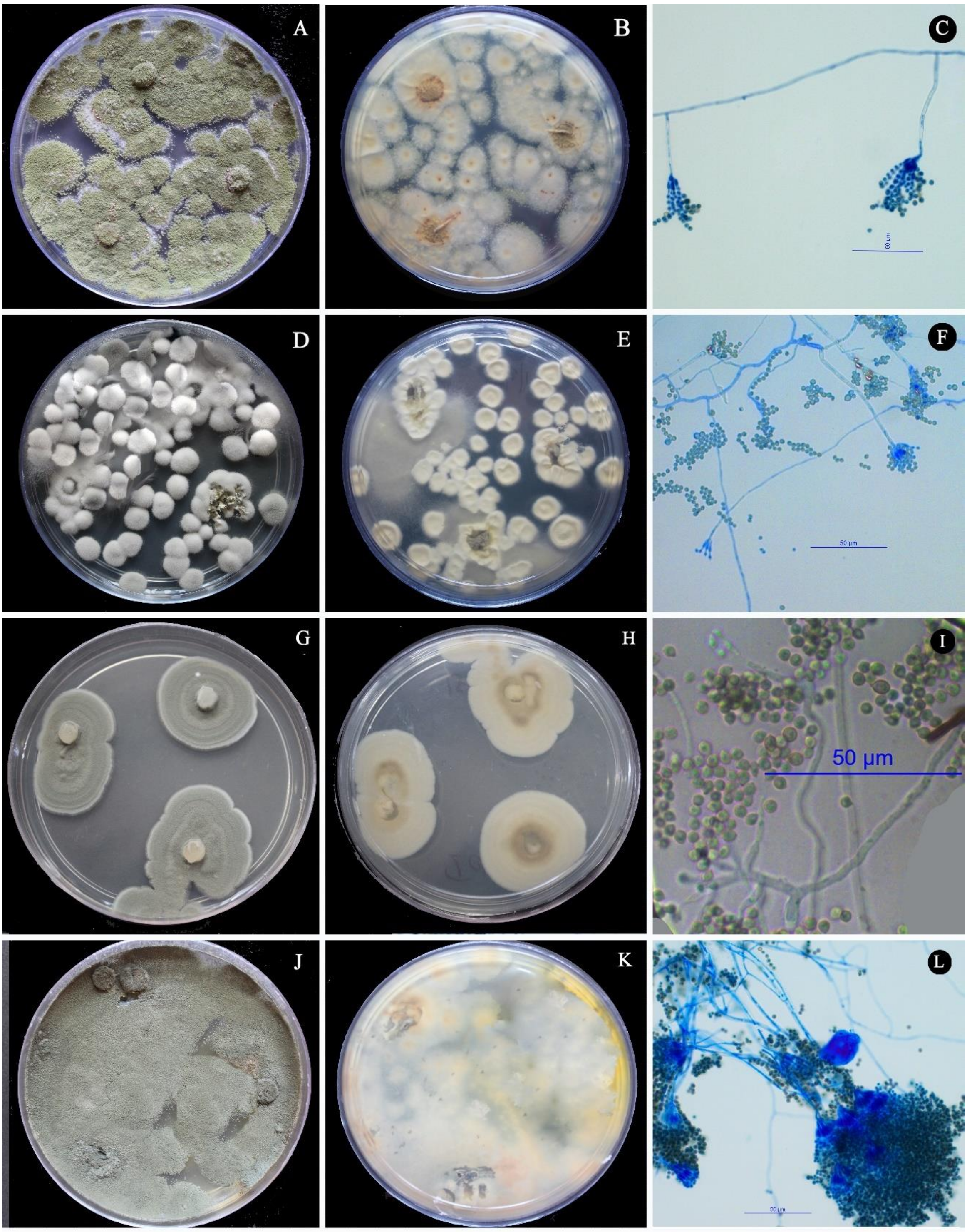

Plate 12. **A – C.** *Penicillium crystallinum*. **D – F.** *Penicillium cyaneum*. **G – I.** *Penicillium granulatum*. **J – L.** *Penicillium janczewskii*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

39. ***Penicillium aurantiogriseum* var. *aurantiogriseum*** Dierckx, in Raper & Thom, A Manual of the Penicillia, pp. 479, Fig: 123 (1949). **(Plate 10, G-I)**

Synonyms: *Penicillium brunneoviolaceum* Biourge, La Cellule 33: 145 (1923), *Penicillium carneolutescens* G. Sm., Transactions of the British Mycological Society 22 (3–4): 253 (1938), *Penicillium conditaneum* Westling, Arkiv før Botanik 11 (1): 63 (1911), *Penicillium cordubense* C. Ramírez & A.T. Martínez, Mycopathologia 74 (3): 164 (1981), *Penicillium johanniolii* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 453 (1927), *Penicillium martensii* Biourge, La Cellule 33: 152 (1923), *Penicillium puberulum* Bainier, Bulletin de la Société Mycologique de France 23 (1): 16 (1907).

Description: Colony furrowed, tufted, first in white colour, then in brown shades, reverse cream to brown colour; conidiophores rough walls, 109–268 x 3.5–4 µm; penicilli asymmetrica; conidia elliptical to subglobose, 2–3 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

40. ***Penicillium brevicompactum*** Dierckx, in Raper & Thom, A Manual of the Penicillia, pp. 407, Fig: 106 (1949). **(Plate 10, J-L)**

Synonyms: *Penicillium hagemii* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 448 (1927), *Penicillium patris-mei* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 496 (1927), *Penicillium stoloniferum* Thom, U.S.D.A. Bureau of Animal Industry Bulletin 118: 68 (1910), *Penicillium biourgeianum* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 462 (1927), *Penicillium griseobrunneum* Dierckx, Annales de la Société Scientifique de Bruxelles 25 (1): 88 (1901), *Penicillium brunneostoloniferum* S. Abe ex C. Ramírez, Manual and Atlas of the Penicillia: 412 (1982), *Penicillium monstrosum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 150 (1912), *Penicillium szaferi* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 447 (1927), *Penicillium tabescens* Westling, Arkiv før Botanik 11 (1): 100 (1911).

Description: Colony velvety to lanose, in andover green colour, white colour margin, reverse orange to yellow colour; conidiophores septate, heavy walls, erect, 360–410 x 3–5 µm; penicilli asymmetrica; conidia subglobose, 2.6–3 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

41. ***Penicillium capsulatum*** Raper & Fennell., in Raper & Thom, A Manual of the Penicillia, pp. 242, Fig: 66,67 (1949). **(Plate 11, A-C)**

Synonyms: Nil.

Description: Colony tough, raised in the central area, grey-green shade, reverse brownish shade; conidiophores short, smooth-walled, irregular branching, 11–62 x 2.3–2.6 µm; penicilli monoverticillata; conidia elliptical, 2.7–3.3 x 1.8–2.3 µm.

Distribution: Isolated from Iringole Kavu.

42. ***Penicillium chermesinum*** Biourge, in Raper & Thom, A Manual of the Penicillia, pp. 206, Fig: 56 (1949). **(Plate 11, D-F)**

Synonyms: *Penicillium vietnamense* V.D. Nguyen & T.T. Pham, Mycobiology 50 (3): 157 (2022).

Description: Colony radially wrinkled, surface tufted, granular, colourless exudates present, greenish grey shade, reverse clay shade; conidiophores borne as short branches, smooth-walled, 16–49 x 2–2.4 µm; penicilli monoverticillata; conidia elliptical, 2–2.2 x 1.4–2.1 µm.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

43. ***Penicillium chrysogenum*** Thom, in Raper & Thom, A Manual of the Penicillia, pp. 359, Fig: 95 (1949). **(Plate 11, G-I)**

Synonyms: *Penicillium chrysogenum* var. *chrysogenum*, *Penicillium cyaneofulvum* Biourge, La Cellule 33: 174 (1923), *Penicillium harmonense* Baghd., Novosti Sistematiki Nizshikh Rastenii 5: 102 (1968), *Penicillium notatum* Westling, Arkiv før Botanik 11 (1): 95 (1911), *Penicillium brunneorubrum* Dierckx, Annales de la Société Scientifique de Bruxelles 25 (1): 88 (1901), *Penicillium aromaticum* f. *microsporum* Romankova, Uchenn. Zap. Leningr. Univ. Zhadanov: 102 (1955), *Penicillium chlorophaeum* Biourge, La Cellule 33: 271 (1923), *Penicillium fluorescens* Laxa, Zentralbl. Bakteriol. 2. Abt. 86 (5–7): 160 (1932), *Penicillium griseoroseum* Dierckx, Annales de la Société Scientifique de Bruxelles 25 (1): 89 (1901), *Penicillium roseocitreum* Biourge, La Cellule 33: 184 (1923), *Penicillium flavidomarginatum* Biourge, La Cellule 33: 150 (1923), *Penicillium citreoroseum* Dierckx, Ann. Soc. Sci. Bruxelles 25 (1): 86 (1901).

Description: Colony loose textured, sulcations present, in grey-green colour, white colour margin, yellow colour exudates present, PDA colour changes to yellow,

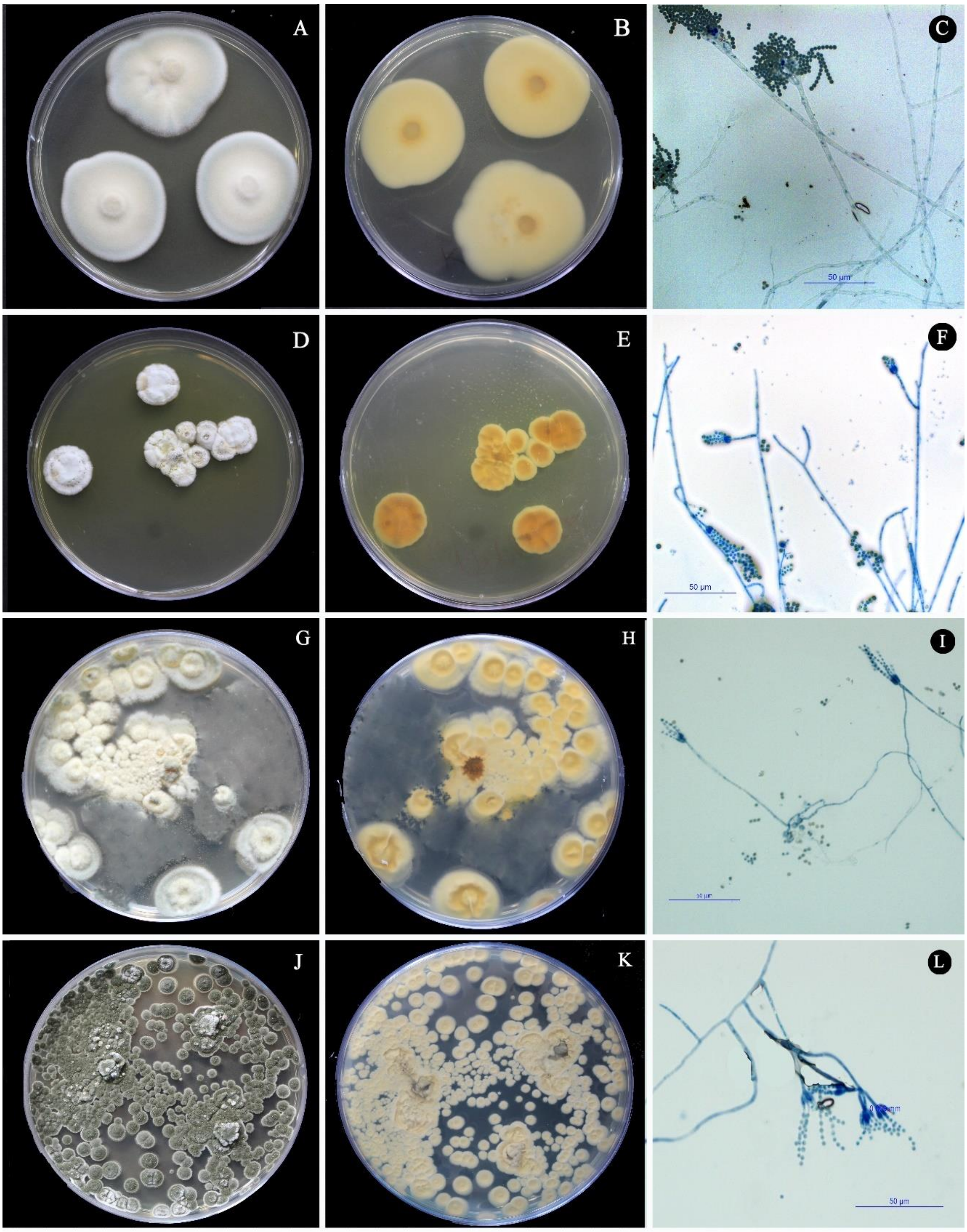

Plate 13. **A – C.** *Penicillium janthinellum.* **D – F.** *Penicillium javanicum.* **G – I.** *Penicillium lividum.* **J – L.** *Penicillium miczynskii.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

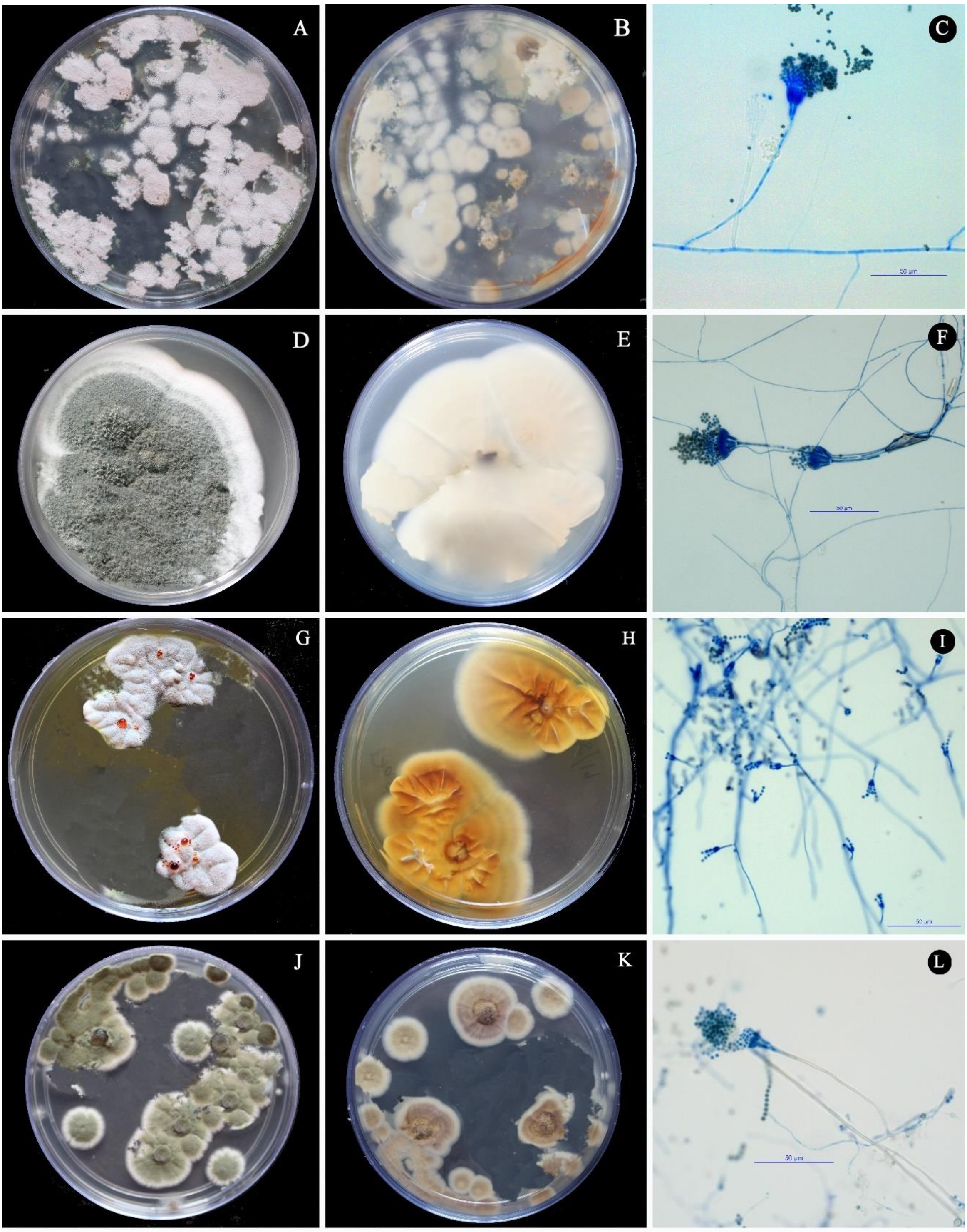

Plate 14. **A – C.** *Penicillium novae-zeelandiae.* **D – F.** *Penicillium paxilli.* **G – I.** *Penicillium restrictum*. **J – L.** *Penicillium roqueforti.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

reverse bright yellow to orange colour; conidiophores smooth-walled, 153–305 x 2–3 µm; penicilli asymmetrica; conidia elliptical, 3–4 x 2–3 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

44. ***Penicillium citrinum*** Thom, in Raper & Thom, A Manual of the Penicillia, pp. 345, Fig: 92 (1949). **(Plate 11, J-L)**

Synonyms: *Penicillium botryosum* Bat. & H. Maia, Anais da Sociedade de Biologia de Pernambuco 15 (1): 159 (1957), *Penicillium implicatum* Biourge, Cellule 33: 278 (1923), *Penicillium implicatum* var. *implicatum*, *Penicillium sartoryi* Thom, The Penicillia: 233 (1930), *Penicillium aurifluum* Biourge, La Cellule 33: 250 (1923), *Penicillium citrinum* var. *pseudopaxilli* Martínez & Ramírez, *Penicillium phaeojanthinellum* Biourge, La Cellule 33: 289 (1923), *Citromyces subtilis* Bainier & Sartory, Bulletin de la Société Mycologique de France 28: 46 (1912), *Penicillium subtile* (Bainier & Sartory) Biourge, La Cellule 33: 106 (1923), *Penicillium sartorii* Thom (1930).

Description: Colony floccose, sulcations present, in grey-green colour, PDA changes to yellow, reverse orange to yellow shade; conidiophores smooth-walled, 76–203 x 1.6–2.8 µm; penicilli have terminal cluster of metulae; conidia globose, 2.5–2.8 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

45. ***Penicillium crystallinum*** (Kwon-Chung & Fennell) Samson, Houbraken, Visagie & Frisvad, in Raper & Fennell, The Genus *Aspergillus*, pp. 471, Fig: 102 (1965). **(Plate 12, A-C)**

Synonyms: *Aspergillus crystallinus* Kwon-Chung & Fennell, The Genus Aspergillus: 471 (1965).

Description: Colony floccose, colourless exudates present, yellowish green to pois green in colour, reverse in cream brown shade; conidiophores thin walls, septate, 72–200 x 2–6 µm; penicilli monoverticillata; conidia globose, 4 µm in diameter.

Distribution: Isolated from Iringole Kavu.

46. ***Penicillium cyaneum*** (Bainier & Sartory) Biourge, in Raper & Thom, A Manual of the Penicillia, pp. 244, Fig: 68 (1949). **(Plate 12, D-F)**

Synonyms: *Citromyces cyaneus* Bainier & Sartory, Bulletin de la Société Mycologique de France 29: 157 (1913).

Description: Colony floccose, central areas raised, radially furrowed, in bluish grey-green colour, reverse yellow shade; conidiophores borne as short branches, smooth-walled, 76–147 x 1.3–2.5 µm; penicilli monoverticillata; conidia elliptical, ends pointed, 2.6–3 x 2–2.3 µm.

Distribution: Isolated from Iringole Kavu.

47. ***Penicillium granulatum*** Bainier, in Raper & Thom, A Manual of the Penicillia, pp. 544, Fig: 139 (1949). **(Plate 12, G-I)**

Synonyms: Nil.

Description: Colony velvety to floccose, concentric rings present, in glaucous green colour, white margin, reverse cream to brown shade; conidiophores variable in length, 85–150 x 3.5–4 µm; penicilli asymmetrica; conidia elliptical to subglobose, 3–3.8 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

48. ***Penicillium janczewskii*** K. Zaleski, in Raper & Thom, A Manual of the Penicillia, pp. 325, Fig: 87,88 (1949). **(Plate 12, J-L)**

Synonyms: *Penicillium granatense* C. Ramírez, A.T. Martínez & Berer., Mycopathologia 72 (1): 31 (1980), *Penicillium nigricans* Bainier ex Thom, The Penicillia: 351 (1930).

Description: Colony velvety, in olive grey colour, colourless exudates present, reverse cream to yellow shade; conidiophores variable in length, 60–155 x 2.5–3 µm; penicilli divericata; conidia globose, echinulate, 2.6–3 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

49. ***Penicillium janthinellum*** Biourge, in Raper & Thom, A Manual of the Penicillia, pp. 299, Fig: 80,81 (1949). **(Plate 13, A-C)**

Synonyms: Nil.

Description: Colony floccose, tough, surface tufted, first in white colour, then in pale grey colour, reverse yellow shade; conidiophores varying in length, smooth-walled, 190–397 x 3.7 µm; penicilli asymmetrica; conidia globose, 2.4–3.3 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

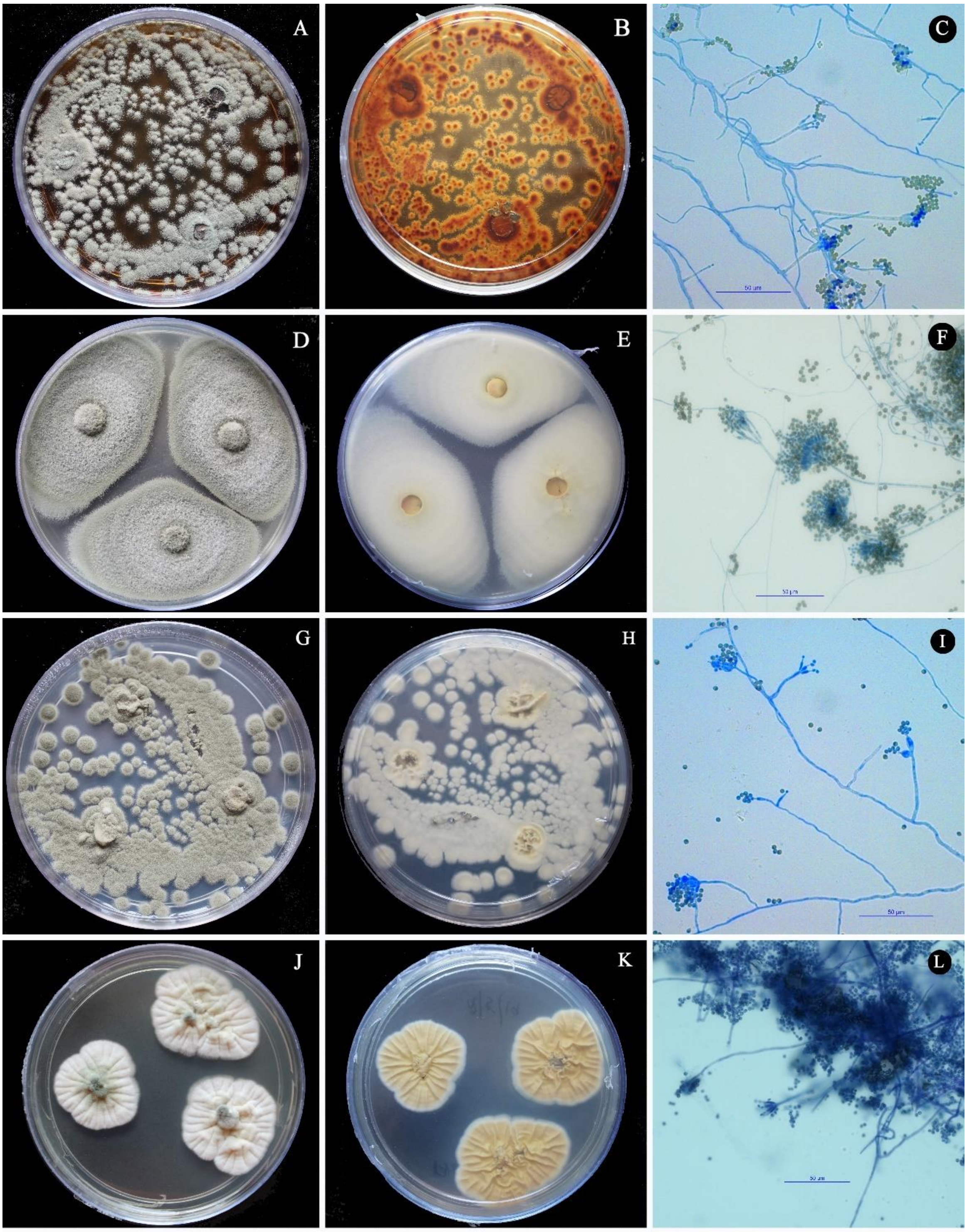

Plate 15. **A – C.** *Penicillium roseopurpureum*. **D – F.** *Penicillium simplicissimum*. **G – I.** *Penicillium spinulosum*. **J – L.** *Penicillium sublateritium*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

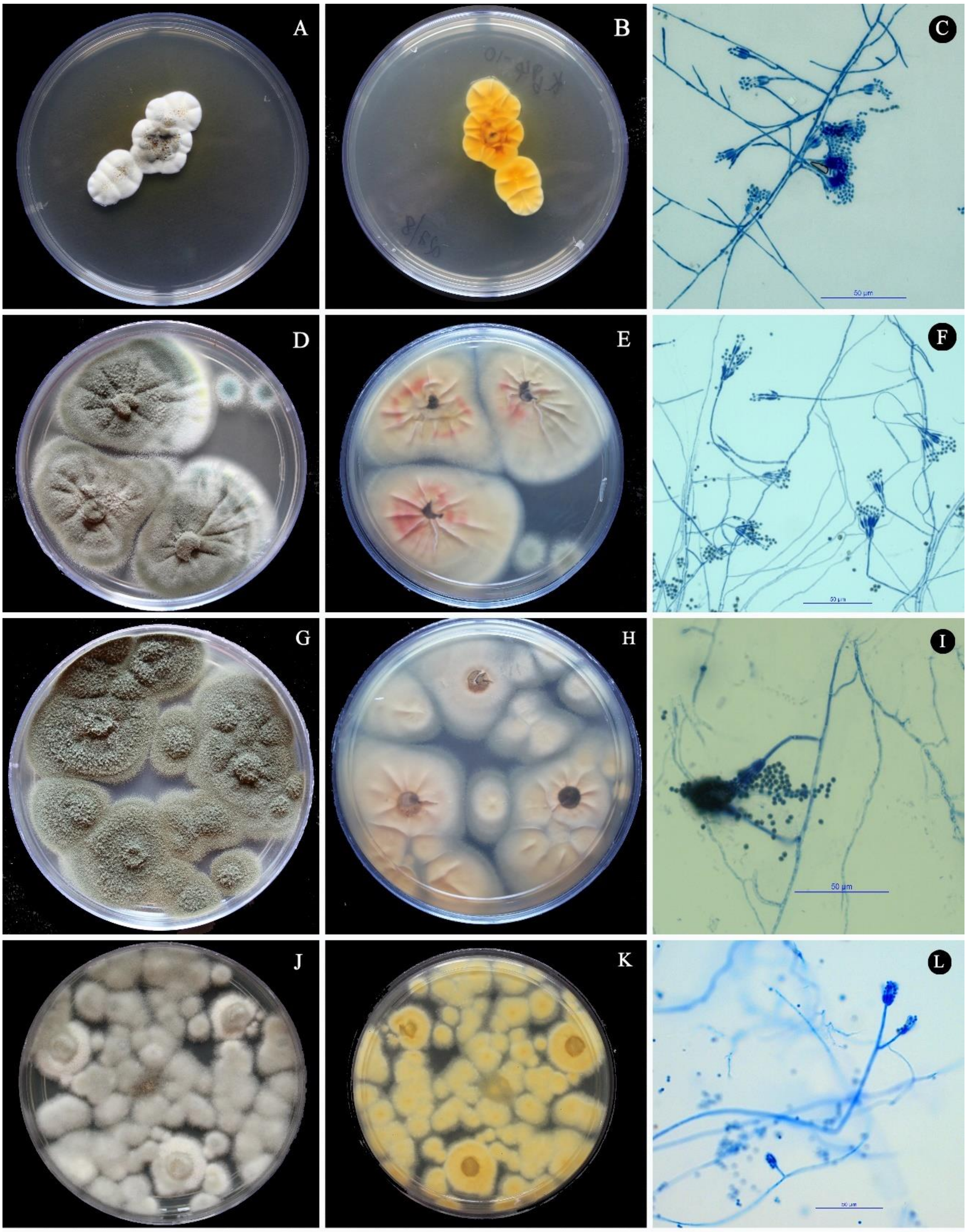

Plate 16. **A – C.** *Penicillium thomii* var. *thomii.* **D – F.** *Penicillium velutinum*. **G – I.** *Penicillium vinaceum*. **J – L.** *Penicillium waksmanii.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

50. ***Penicillium javanicum*** J.F.H. Beyma, in Raper & Thom, A Manual of the Penicillia, pp. 135, Fig: 36 (1949). **(Plate 13, D-F)**

Synonyms: *Carpenteles javanicum* (J.F.H. Beyma) Shear, Mycologia 26 (1): 107 (1934), *Eupenicillium javanicum* (J.F.H. Beyma) Stolk & D.B. Scott, Persoonia 4 (4): 398 (1967), *Penicillium oligosporum* Saito & Minoura, Journal of Fermentation Technology Osaka 26: 3 (1948), *Penicillium indonesiae* Pitt, The genus *Penicillium* and its teleomorphic states *Eupenicillium* and *Talaromyces*: 114 (1980).

Description: Colony floccose, slightly granular, first in white colour, then in yellow shade, yellow colour exudates present, PDA turns to yellow, reverse yellow to reddish shade; conidiophores borne as short branches, smooth-walled, 18–31 x 2–2.4 µm; penicilli monoverticillata; conidia subglobose, 2–2.6 µm long.

Distribution: Isolated from Kollakal Thapovanam.

51. ***Penicillium lividum*** Westling, in Raper & Thom, A Manual of the Penicillia, pp. 190, Fig: 52 (1949). **(Plate 13, G-I)**

Synonyms: Nil.

Description: Colony lanose, first in white colour, then in glaucous grey shade with yellow tinge, reverse yellow shade; conidiophores unbranched, single, long, 98–546 x 2.7–4.3 µm; penicilli monoverticillata; conidia ovate, 3–4 x 2–2.8 µm.

Distribution: Isolated from Poyilkavu.

52. ***Penicillium miczynskii*** K. Zaleski, in Raper & Thom, A Manual of the Penicillia, pp. 309, Fig: 83 (1949). **(Plate 13, J-L)**

Synonyms: *Penicillium sulfureum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 172 (1912).

Description: Colony floccose, raised, greenish grey shade, white margin, colourless exudates present, reverse yellow shade; conidiophores smooth-walled, 68–368 x 2–2.8 µm; penicilli asymmetrica; conidia subglobose, 2–3 µm in diameter.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

53. ***Penicillium novae-zeelandiae*** J.F.H. Beyma, in Raper & Thom, A Manual of the Penicillia, pp. 665, Fig: 167 (1949). **(Plate 14, A-C)**

Synonyms: *Penicillium novae-zelandiae* J.F.H. Beyma (1940).

Description: Colony velvety to floccose, in white to light pink shade, reverse white to brown shade; conidiophores unbranched, long, rough walls, 93.4–316 x 2.7–3.3 µm; penicilli biverticillata; conidia globose, 2–2.6 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

54. ***Penicillium paxilli*** Bainier, in Raper & Thom, A Manual of the Penicillia, pp. 414, Fig: 108 (1949). **(Plate 14, D-F)**

Synonyms: Nil.

Description: Colony velvety to funiculose, centre raised, radial furrows present, in artemisia green colour, large white margins, colourless exudates present, reverse cream colour; conidiophores variable in length, 133–189 x 3.5–4 µm; penicilli asymmetrica; conidia elliptical to subglobose, rough, 2.8–3 µm long.

Distribution: Isolated from Iringole Kavu.

55. ***Penicillium restrictum*** J.C. Gilman & E.V. Abbott, in Raper & Thom, A Manual of the Penicillia, pp. 223, Fig: 61 (1949). **(Plate 14, G-I)**

Synonyms: *Penicillium kazachstanicum* Novobr., Novosti Sistematiki Nizshikh Rastenii 11: 225 (1974), *Citromyces griseus* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 119 (1912), *Penicillium griseum* (Sopp) Biourge, La Cellule 33: 103 (1923), *Penicillium gilmanii* Thom, The Penicillia: 345 (1930).

Description: Colony floccose, first in white colour, then in ash shade, red to yellow colour exudates present, radially wrinkled, reverse yellow to red shade; conidiophores borne as short branches, smooth-walled, 11–14 x 1–2 µm; penicilli monoverticillata; conidia globose, 2–2.3 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

56. ***Penicillium roqueforti*** Thom, in Raper & Thom, A Manual of the Penicillia, pp. 395, Fig: 104,105 (1949). **(Plate 14, J-L)**

Synonyms: *Penicillium conservandi* Novobr., Novosti Sistematiki Nizshikh Rastenii 11: 233 (1974), *Penicillium roqueforti* var. *viride* Datt.-Rubbo, Transactions of the British Mycological Society 22 (1–2): 178 (1938), *Penicillium stilton* Biourge, La Cellule 33: 204 (1923), *Penicillium aromaticum-casei* Sopp ex Sacc., Sylloge Fungorum 22: 1278 (1913), *Penicillium atroviride* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 149 (1912), *Penicillium biourgei* Arnaudi, Boll. Ist. Sieroter. Milan.: 27 (1928), *Penicillium roqueforti* var. *weidemanni* Westling (1911), *Penicillium suaveolens* Biourge, La Cellule 33: 200 (1923), *Penicillium vesiculosum* Bainier, Bulletin de la Société Mycologique de France 23 (1): 10 (1907), *Penicillium*

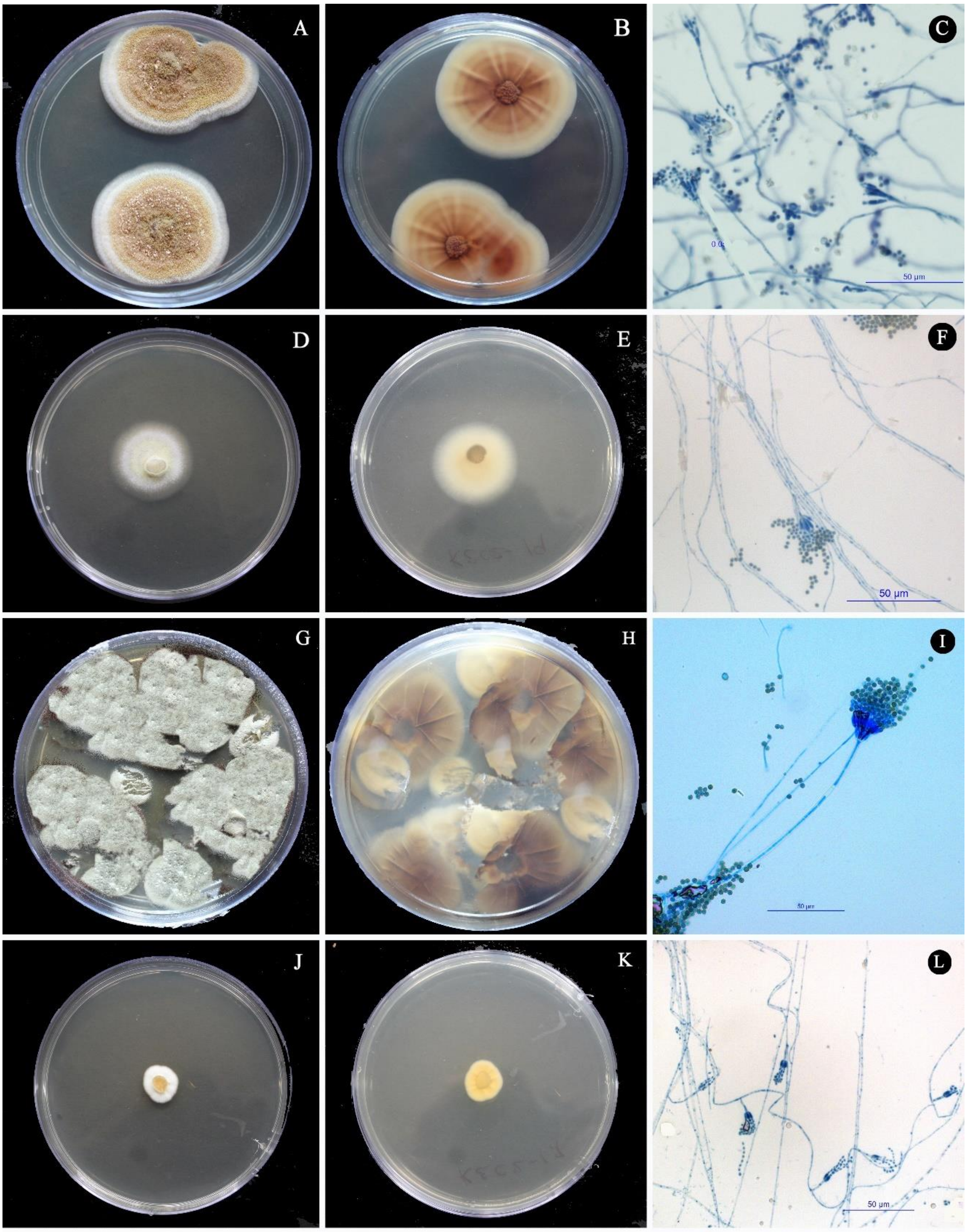

Plate 17. **A – C.** *Penicillium* sp. 1. **D – F.** *Penicillium* sp. 2. **G – I.** *Penicillium* sp. 3. **J – L.** *Penicillium* sp. 4. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

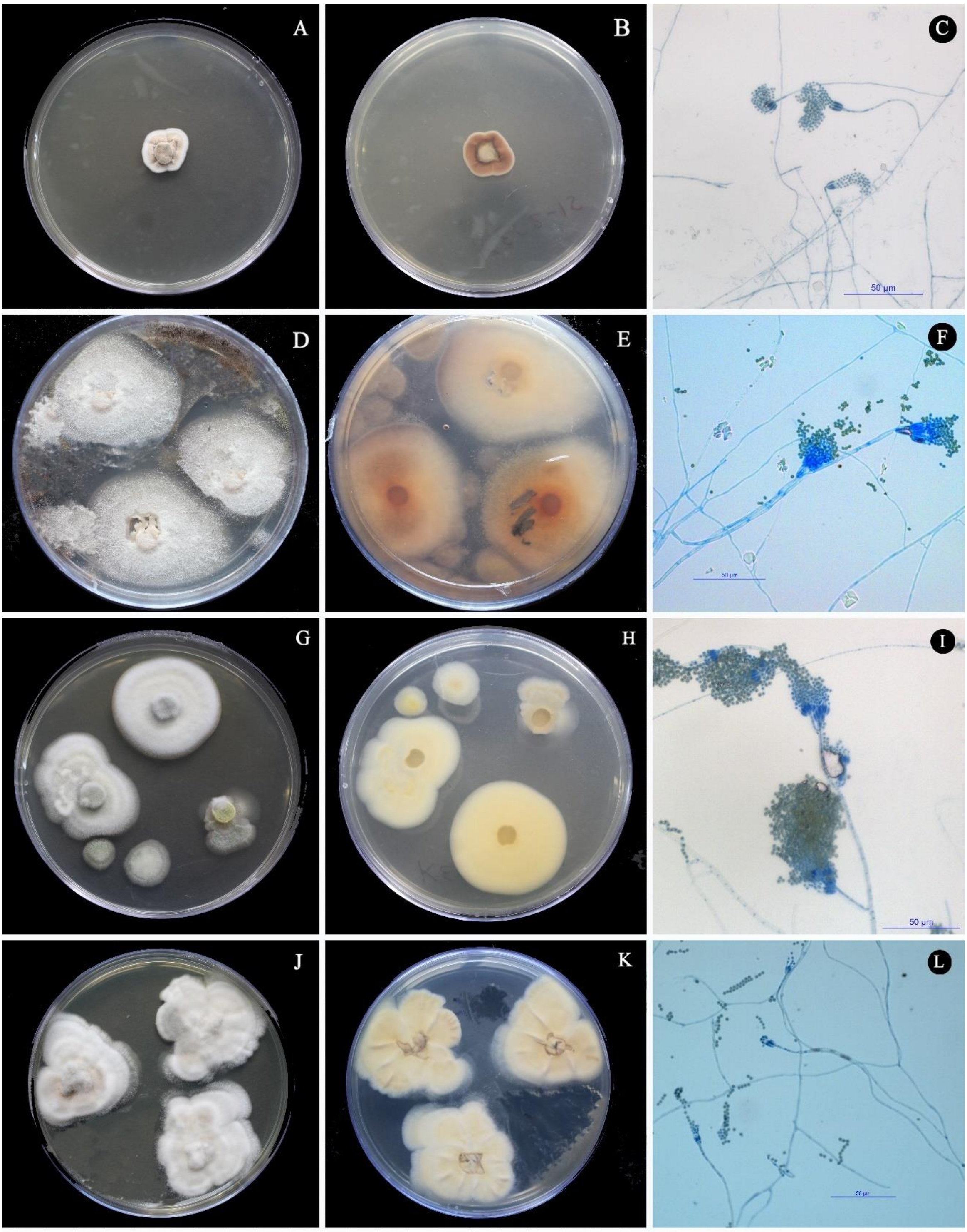

Plate 18. A – C. *Penicillium* sp. 5. **D – F.** *Penicillium* sp. 6. **G – I.** *Penicillium* sp. 7. **J – L.** *Penicillium* sp. 8. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

virescens Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 157 (1912), *Penicillium weidemannii* var. *fuscum* Arnaudi, Boll. Ist. Sieroter. Milan.: 27 (1928), *Penicillium roqueforti* var. *weidemannii* Westling, Arkiv før Botanik 11 (1): 71 (1911), *Penicillium gorgonzolae* Weid., La Cellule 33: 204 (1923), *Penicillium weidemannii* (Westling) Biourge, La Cellule 33: 204 (1923), *Penicillium gorgonzolae* Weid. (1923).

Description: Colony velvety to floccose, in pea green colour, white margin, reverse brown shade; conidiophores borne as short branches, smooth-walled, 103–137 x 3–4 µm; penicilli asymmetrica; conidia globose, 3–4.2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

57. ***Penicillium roseopurpureum*** Dierckx, in Raper & Thom, A Manual of the Penicillia, pp. 218 (1949). **(Plate 15, A-C)**

Synonyms: *Citromyces cesiae* Bainier & Sartory, Bulletin de la Société Mycologique de France 29: 148 (1913), *Penicillium cesiae* (Bainier & Sartory) Biourge, La Cellule 33: 101 (1923), *Penicillium carminoviolaceum* Dierckx, Annales de la Société Scientifique de Bruxelles 25 (1): 86 (1901), *Penicillium carmineoviolaceum* Dierckx (1901), *Penicillium carmino-violaceum* Dierckx (1901).

Description: Colony floccose, centre raised, in greyish green colour, PDA to red-brown colour, reverse red-brown shade; conidiophores borne as short branches, 27–59 x 1.9–2.3 µm; penicilli monoverticillata; conidia globose, delicately roughened, 2.3–2.6 µm in diameter.

Distribution: Isolated from Iringole Kavu.

58. ***Penicillium simplicissimum*** (Oudem.) Thom, in Raper & Thom, A Manual of the Penicillia, pp. 304, Fig; 81 (1949). **(Plate 15, D-F)**

Synonyms: *Spicaria simplicissima* Oudem., Nederlandsch Kruidkundig Archief 2 (3): 763 (1903), *Penicillium ciegleri* Quintan., Av. Aliment. Majora Anim.: 336 (1982), *Penicillium glaucolanosum* Chalab., Not. Syst. Crypt. Inst. bot. Acad. Sci. USSR: 161–167 (1950), *Penicillium novae-caledoniae* var. *album* C. Ramírez & A.T. Martínez, Mycopathologia 74 (1): 47 (1981), *Penicillium populi* J.F.H. Beyma, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 96: 421 (1937).

Description: Colony velvety to floccose, first white, then in grey-green colour, colourless exudates present, reverse ream to yellow shade; conidiophores varying in length, rough-walled; penicilli asymmetrica; conidia subglobose, echinulate, 2.5–3 µm in diameter.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

59. ***Penicillium spinulosum*** Thom, in Raper & Thom, A Manual of the Penicillia, pp. 180, Fig; 51 (1949). **(Plate 15, G-I)**

Synonyms: *Penicillium abeanum* G. Sm., Transactions of the British Mycological Society 46 (3): 333 (1963), *Penicillium mucosum* Stapp & Bortels, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 93: 51 (1935), *Penicillium toxicarium* I. Miyake, Japanese Journal of Medical Progress 34: 161 (1947), *Penicillium trzebinskii* var. *magnum* Sakag. & S. Abe, Journal of General and Applied Microbiology Tokyo 2 (1–2): 62 (1956), *Penicillium virididorsum* Biourge, La Cellule 33: 306 (1923), *Penicillium baiicola* Biourge, La Cellule 33: 305 (1923), *Penicillium brunneoviride* Szilvinyi, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 103: 144 (1941), *Penicillium internascens* Szilvinyi, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 103: 148 (1941), *Penicillium mediocre* Stapp & Bortels, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 93: 50 (1935), *Penicillium tannophilum* Stapp & Bortels, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 93: 52 (1935), *Penicillium tannophagum* Stapp & Bortels, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 93: 52 (1935), *Penicillium flavocinereum* Biourge, La Cellule 33: 293 (1923).

Description: Colony velvety to floccose, in sage green colour, reverse colourless; conidiophores varying in length, 27–97 x 2.6–2.7 µm; penicilli monoverticillata; conidia subglobose to elliptical, 2.4–3.2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

60. ***Penicillium sublateritium*** Biourge, in Raper & Thom, A Manual of the Penicillia, pp.203, Fig; 55 (1949). **(Plate 15, J-L)**

Synonyms: Nil.

Description: Colony velvety, radially furrowed, centre raised, first white, then in celandine green colour, reverse yellow shade; conidiophores less than 100 µm in length by 2 µm, smooth-walled, 16–49 x 2–2.4 µm; penicilli monoverticillata; conidia obpyriform, apiculate, 4–5 x 3 µm.

Distribution: Isolated from Kollakal Thapovanam.

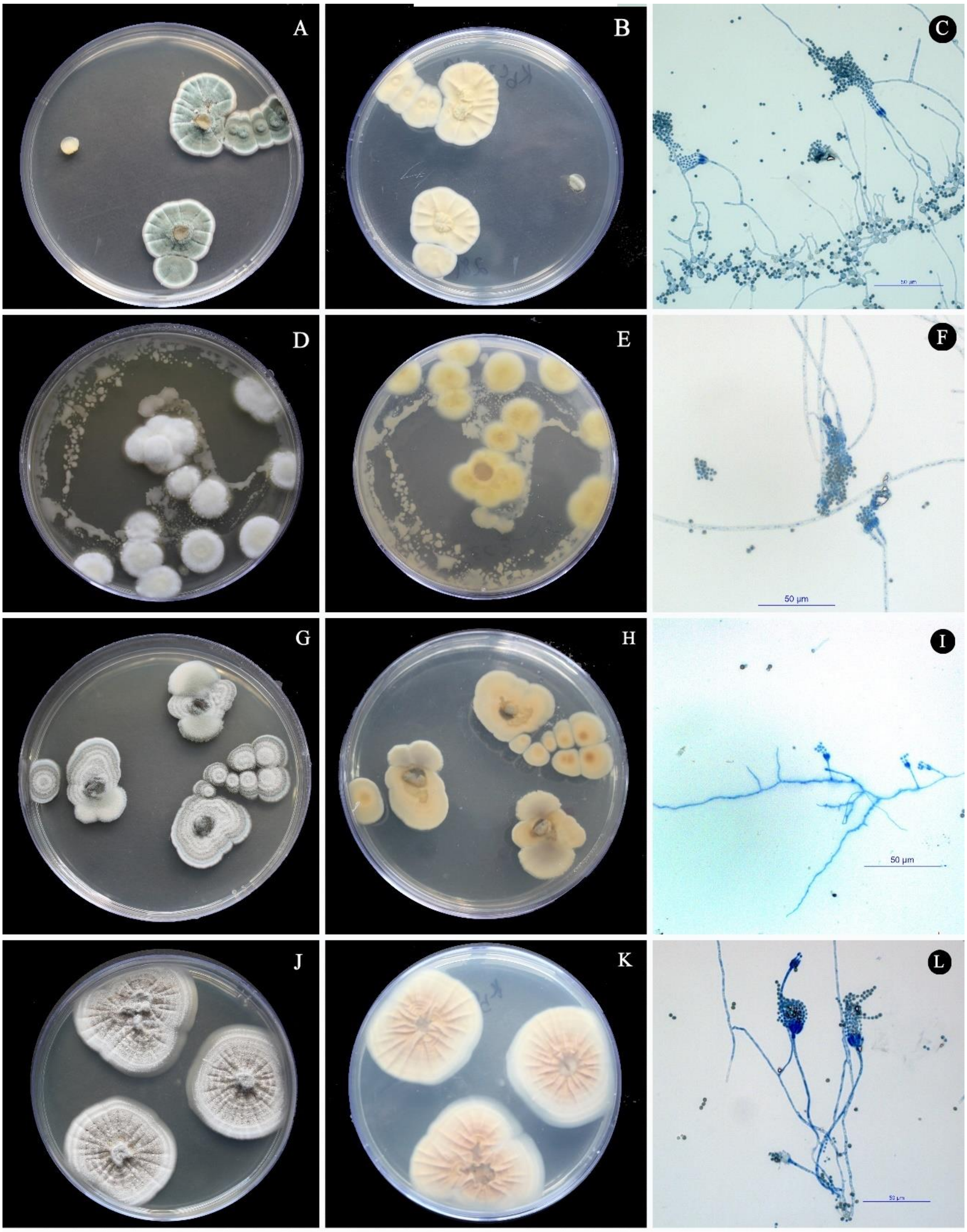

Plate 19. **A – C.** *Penicillium* sp. 9. **D – F.** *Penicillium* sp. 10. **G – I.** *Penicillium* sp. 11. **J – L.** *Penicillium* sp. 12 **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

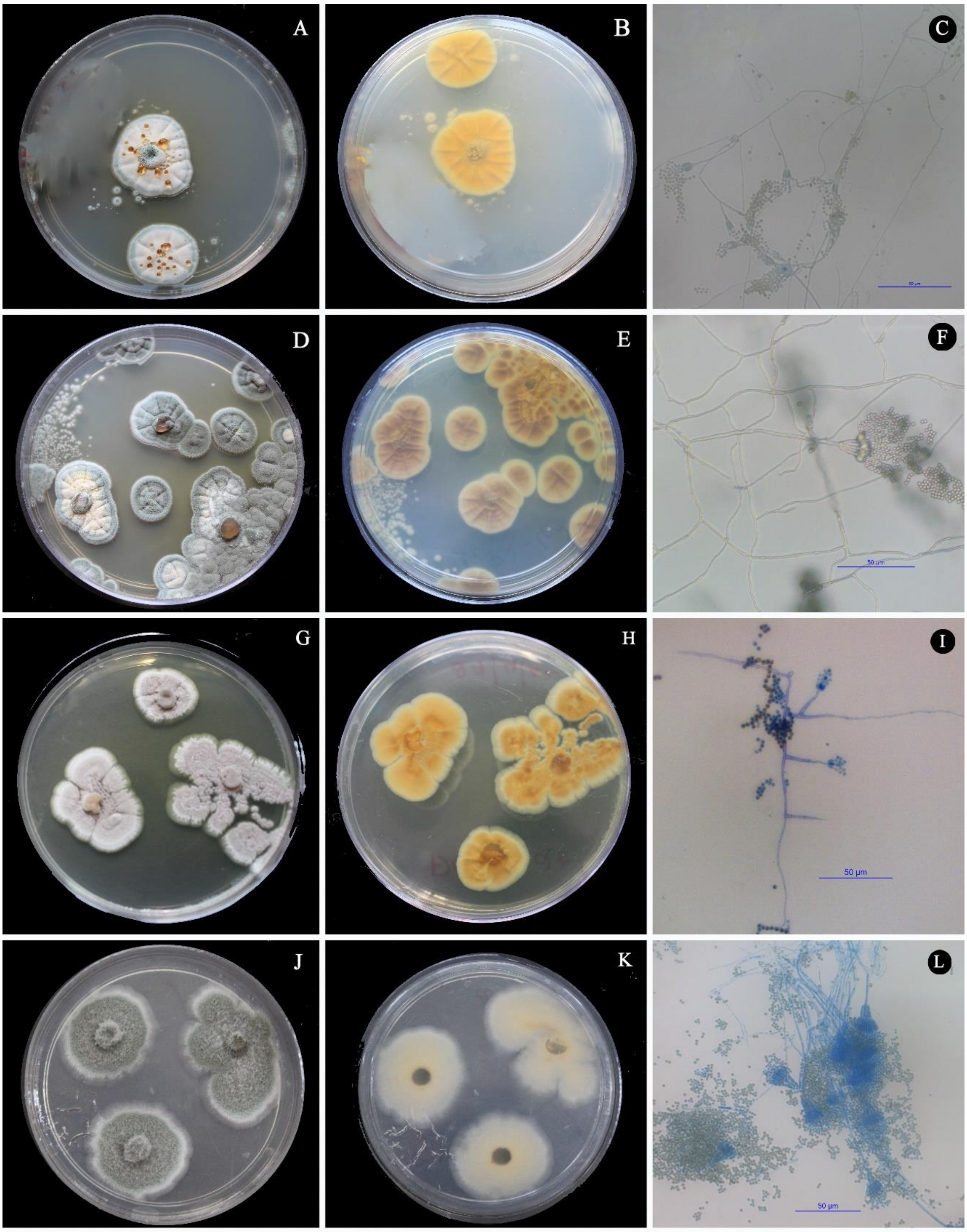

Plate 20. **A – C.** *Penicillium* sp. 13. **D – F.** *Penicillium* sp. 14. **G – I.** *Penicillium* sp. 15. **J – L.** *Penicillium* sp. 16. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

61. ***Penicillium thomii* var. *thomii*** Maire., in Raper & Thom, A Manual of the Penicillia, pp.156, Fig; 43 (1949). **(Plate 16, A-C)**

Synonyms: *Citromyces thomii* Maire ex Sacc., Syll. Fung. 25: 683 (1931), *Penicillium lividum* var. *thomii* (Maire) Stolk & Samson, Advances in *Penicillium* and *Aspergillus* Systematics: 170 (1986), *Penicillium parallelosporum* Y. Sasaki, Journal of the Faculty of Agriculture of the Hokkaido Imperial University 49: 147 (1950), *Penicillium yezoense* Hanzawa, J. Agric. Chem. Soc. Japan: 774 (1943), *Penicillium flavescens* (S. Abe) L. Wang, Journal of General and Applied Microbiology Tokyo 2 (1–2) (1956), *Penicillium yezoensum* Hanzawa (1943).

Description: Colony cottony, tough, first white, then in grey-green colour, brown colour exudates present, reverse yellow to brown shade; conidiophores echinulate, 17–20 x 2–3 µm; penicilli monoverticillata; conidia elliptical, 3–3.8 x 1–2 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

62. ***Penicillium velutinum*** J.F.H. Beyma, in Raper & Thom, A Manual of the Penicillia, pp.250, Fig; 68 (1949). **(Plate 16, D-F)**

Synonyms: *Penicillium pinetorum* M. Chr. & Backus, Mycologia 53 (5): 457 (1961).

Description: Colony velvety to floccose, centre raised, radially furrowed, in bluish grey-green colour, white margin, reverse orange to red shade; conidiophores simple, smooth-walled, 52–81 x 1.5–2 µm; penicilli ramigenous; conidia globose, rough, echinulate, 2–3 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

63. ***Penicillium vinaceum*** J.C. Gilman & E.V. Abbott, in Raper & Thom, A Manual of the Penicillia, pp.234, Fig; 65 (1949). **(Plate 16, G-I)**

Synonyms: Nil.

Description: Colony funiculose, in grey-green colour, colourless exudates present, reverse red shade; conidiophores short branches, smooth-walled, 27–43 x 2–2.4 µm; penicilli monoverticillata; conidia globose, 1.6–2.2 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

64. ***Penicillium waksmanii*** K. Zaleski, in Raper & Thom, A Manual of the Penicillia, pp.246, Fig; 68 (1949). **(Plate 16, J-L)**

Synonyms: *Penicillium rivolii* K. Zaleski, Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B., Sci. Nat. 1927: 471 (1927), *Penicillium rivolii var. rivolii.*

Description: Colony cottony, first in white colour, then in olive grey colour, reverse yellow shade; conidiophores smooth-walled, 95.6–174 x 2–4 µm; penicilli monoverticillata; conidia globose, 2–2.5 µm in diameter.

Distribution: Isolated from Poyilkavu.

65. ***Penicillium* sp. 1** **(Plate 17, A-C)**

Synonyms: Nil.

Description: Colony floccose, in yellow-brown shade, white margin, yellow sclerotia present, yellow colour exudates present, reverse brown to maroon shade, radial furrows present; conidiophores borne as short branches, 39–58 x 2–3 µm; penicilli asymmetrica; conidia small, ovoid, 1.1–1.3 x 0.9–1.1 µm.

Distribution: Isolated from Kollakal Thapovanam.

66. ***Penicillium* sp. 2** **(Plate 17, D-F)**

Synonyms: Nil.

Description: Colony velvety to floccose, in white to light yellow colour, reverse yellow shade; conidiophores long, thin, up to 400 µm long; penicilli monoverticillata; conidia globose, 2.2–2.3 µm in diameter.

Distribution: Isolated from Poyilkavu.

67. ***Penicillium* sp. 3** **(Plate 17, G-I)**

Synonyms: Nil.

Description: Colony tufted, tough, in olive green to white colour, colourless exudates present, reverse brown shade; conidiophores long, septate, smooth-walled, up to 200 µm long x 1.1–3.3 µm wide; penicilli biverticillata; conidia globose, echinulate, 2.6–3.3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

68. ***Penicillium* sp. 4** **(Plate 17, J-L)**

Synonyms: Nil.

Description: Colony cottony, in white colour, striations present, reverse yellow shade; conidiophores borne as short branches, 10.7–13.4 x 1–1.7 µm; penicilli monoverticillata; conidia cylindrical, 1.9–2.7 x 1.3–1.5 µm.

Distribution: Isolated from Poyilkavu.

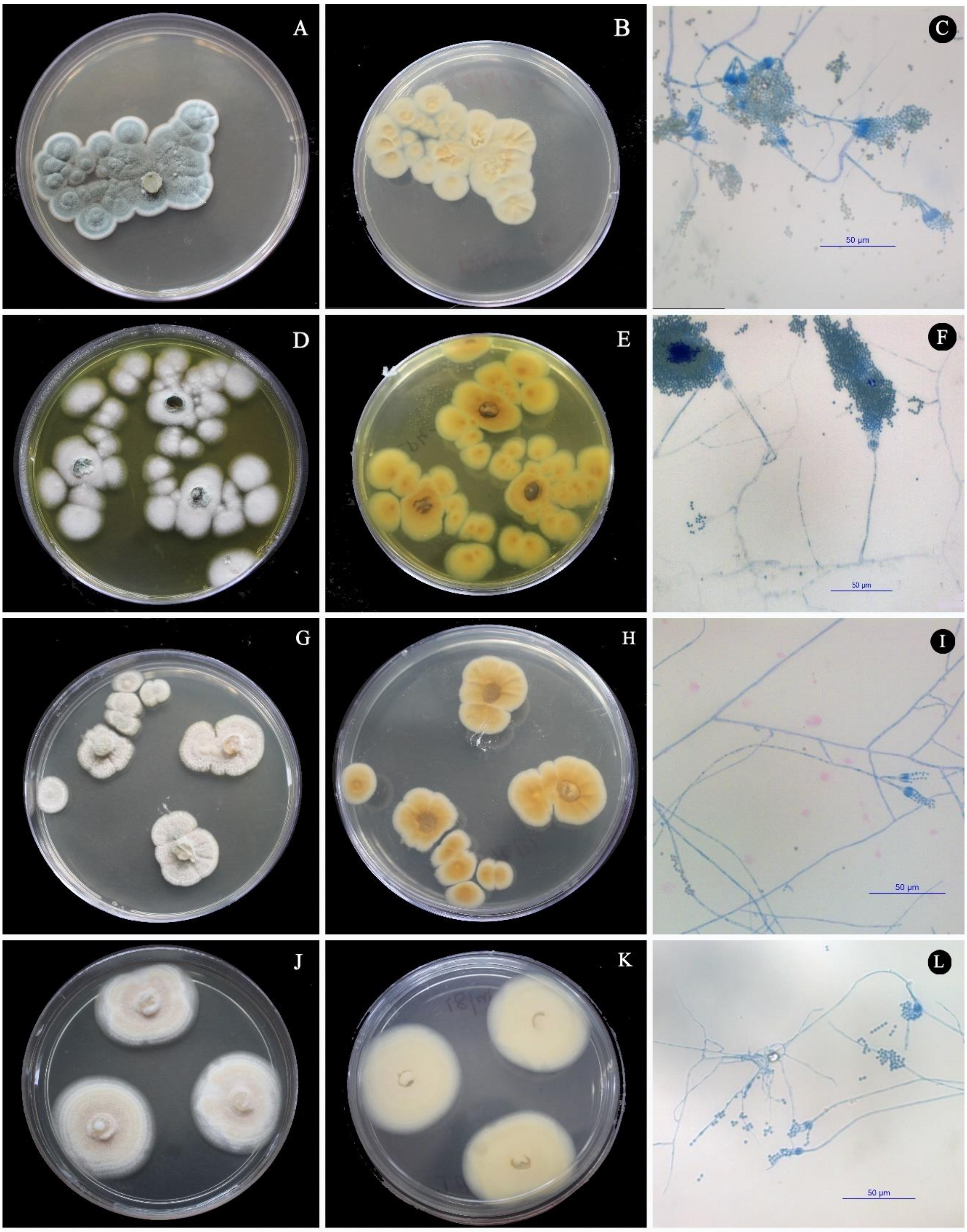

Plate 21. **A – C.** *Penicillium* sp. 17. **D – F.** *Penicillium* sp. 18. **G – I.** *Penicillium* sp. 19. **J – L.** *Penicillium* sp. 20. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

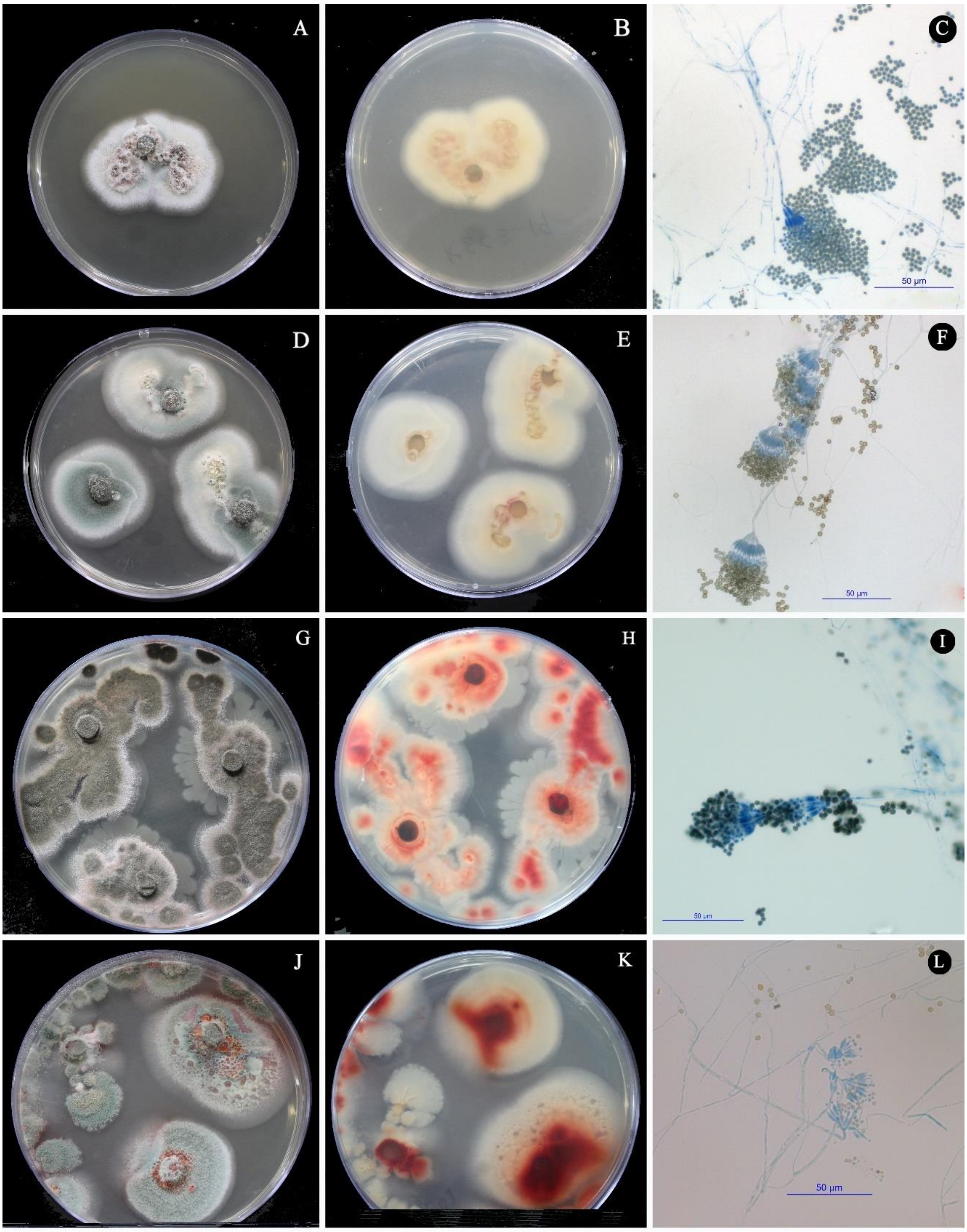

Plate 22. **A – C.** *Penicillium* sp. 21. **D – F.** *Penicillium* sp. 22. **G – I.** *Talaromyces aculeatus*. **J – L.** *Talaromyces atroroseus*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

69. ***Penicillium*** **sp. 5** **(Plate 18, A-C)**

Synonyms: Nil.

Description: Colony velvety, striations present, in light brown shade, white margin, reverse dark brown shade; conidiophores simple, smooth-walled, 52–110.9 x 1.1–1.6 µm; penicilli monoverticillata; conidia globose, 1.3–1.8 µm in diameter.

Distribution: Isolated from Poyilkavu.

70. ***Penicillium*** **sp. 6** **(Plate 18, D-F)**

Synonyms: Nil.

Description: Colony floccose, in white colour, reverse cream to red colour; conidiophores long, simple, 176–215 x 3.6–4 µm; penicilli biverticillata; conidia elliptical to fusifrom, 2.3–2.7 x 1.9–2.4 µm.

Distribution: Isolated from Iringole Kavu.

71. ***Penicillium*** **sp. 7** **(Plate 18, G-I)**

Synonyms: Nil.

Description: Colony floccose, in off-white colour, reverse yellow shade; conidiophores branched, smooth-walled, 50–184 x 1.4–2.7 µm; penicilli polyverticillata; conidia ovate, 2.7–3 x 2.2–2.6 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

72. ***Penicillium*** **sp. 8** **(Plate 18, J-L)**

Synonyms: Nil.

Description: Colony cottony, tough, colourless exudates present, in white colour, reverse cream shade; conidiophores long, smooth-walled, up to 300 µm long; penicilli monoverticillata; conidia globose, 2.8–3 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

73. ***Penicillium*** **sp. 9** **(Plate 19, A-C)**

Synonyms: Nil.

Description: Colony velvety, centre raised, in green to bluish green colour, white margin, colourless exudates present, striations present, reverse yellow shade; conidiophores simple, unbranched, arising from the marginal areas, 36–74 x 1.5–2 µm; penicilli monoverticillata; conidia subglobose, 2–3 µm in diameter.

Distribution: Isolated from Poyilkavu.

74. ***Penicillium*** **sp. 10** **(Plate 19, D-F)**

Synonyms: Nil.

Description: Colony cottony, slimy, in white to cream colour, reverse yellow shade; conidiophores long, branched, up to 477 µm long; penicilli asymmetrica; conidia oval, apicular, 2.7–3.4 x 2.5–3.1 µm.

Distribution: Isolated from Poyilkavu.

75. *Penicillium* sp. 11 **(Plate 19, G-I)**

Synonyms: Nil.

Description: Colony floccose, in ash to off-white shade, white margin, concentric rings present, reverse yellow shade; conidiophores as short branches, erect, 10–14.6 x 1.3–1.6 µm; penicilli monoverticillata; conidia globose, 1.6–2 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

76. *Penicillium* sp. 12 **(Plate 19, J-L)**

Synonyms: Nil.

Description: Colony velvety, tough, in peach-brown shade, silver colour exudates present, concentric rings present, radially furrowed, reverse brown to cream shade; conidiophores simple, rough-walled, 44–109 x 2–3 µm; penicilli monoverticillata; conidia globose, 2–2.4 µm in diameter.

Distribution: Isolated from Poyilkavu.

77. *Penicillium* sp. 13 **(Plate 20, A-C)**

Synonyms: Nil.

Description: Colony velvety to tufted, radially furrowed, in cream yellow shade, bluish green margin, orange colour exudates present, reverse orange-yellow shade; conidiophores unbranched, smooth-walled, simple, 38.9–39.2 x 1.3–1.8 µm; penicilli monoverticillata; conidia globose, 1.6–2.5 µm in diameter.

Distribution: Isolated from Iringole Kavu.

78. *Penicillium* sp. 14 **(Plate 20, D-F)**

Synonyms: Nil.

Description: Colony velvety, surface tufted, centre raised, radially furrowed, first in slate grey colour, then in cream colour, yellow colour exudates present, PDA changes to yellow, reverse yellow to brown shade; conidiophores unbranched, rough-walled, 84–112 x 2.9–3.7 µm; penicilli biverticillata; conidia globose, 1.9–2.4 µm in diameter.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

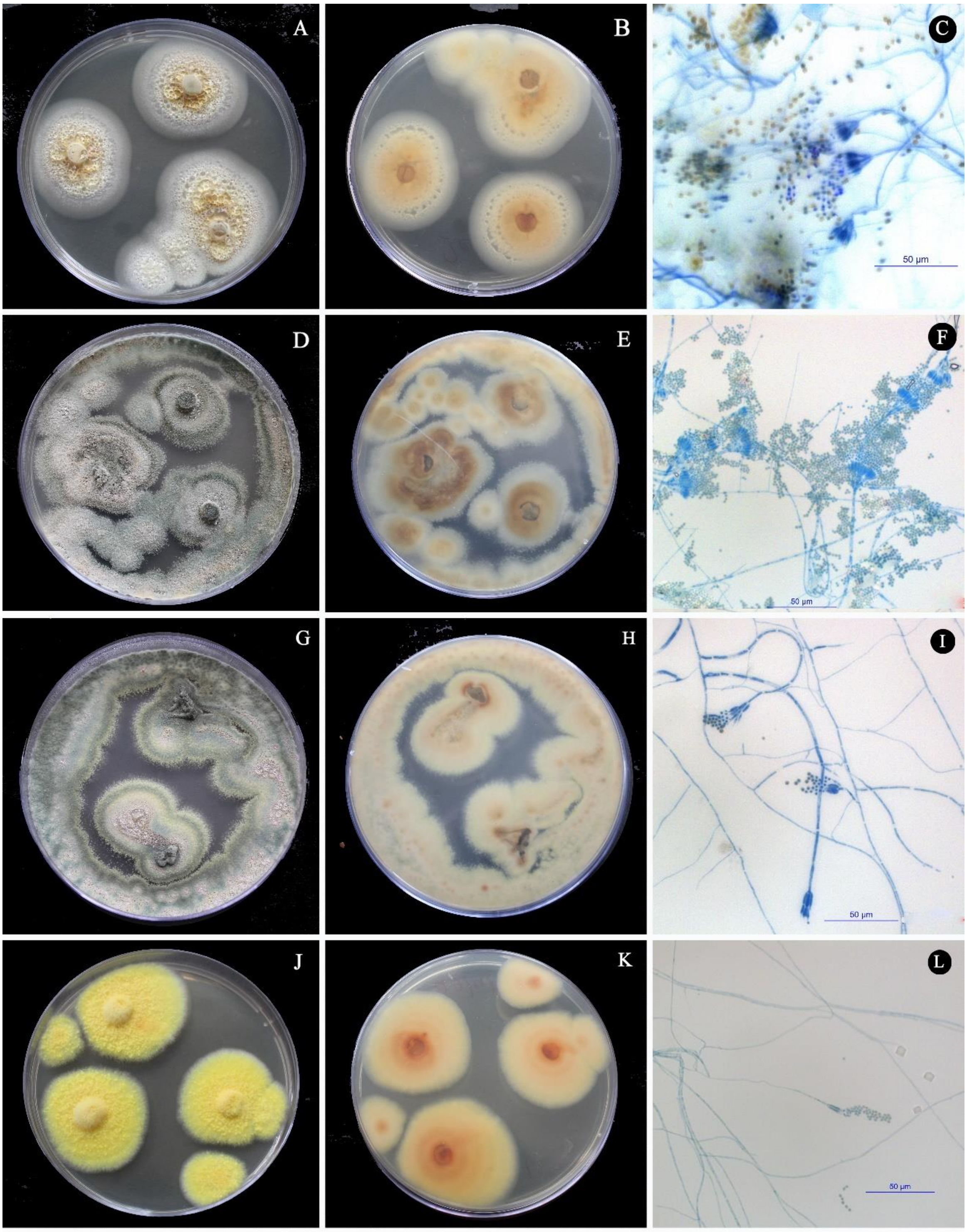

Plate 23. **A – C.** *Talaromyces brunneus*. **D – F.** *Talaromyces diversus*. **G – I.** *Talaromyces duclauxii*. **J – L.** *Talaromyces flavus*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

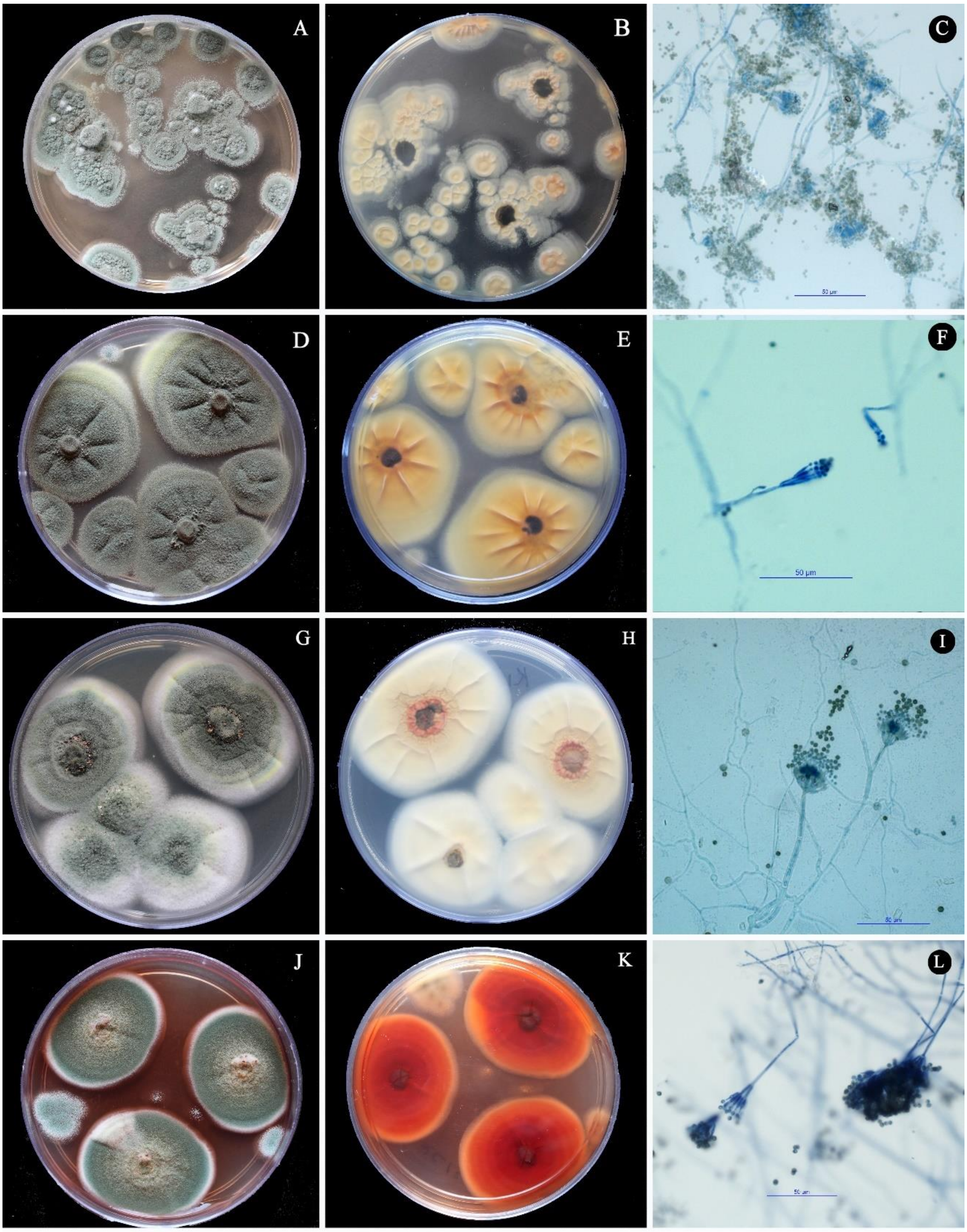

Plate 24. **A – C.** *Talaromyces funiculosus*. **D – F.** *Talaromyces islandicus*. **G – I.** *Talaromyces piceae*. **J – L.** *Talaromyces purpureogenus*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

79. ***Penicillium*** **sp. 15** **(Plate 20, G-I)**

Synonyms: Nil.

Description: Colony velvety to granular, rosette appearance, in peach colour, white margin, sulcations present, reverse yellow-brown shade; conidiophores short, simple, 18–29.4 x 2.3–2.7 µm; penicilli monoverticillata; conidia globose, 2.5–3.1 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

80. ***Penicillium*** **sp. 16** **(Plate 20, J-L)**

Synonyms: Nil.

Description: Colony funiculose, in olive green colour, white margin, reverse cream to yellow shade; conidiophores unbranched, long, smooth-walled, up to 250 µm long; penicilli biverticillata; conidia globose to subglobose, rough, 2.2–2.6 µm in diameter.

Distribution: Isolated from Iringole Kavu.

81. ***Penicillium*** **sp. 17** **(Plate 21, A-C)**

Synonyms: Nil.

Description: Colony velvety to tufted, tough, centre raised, sulcations present, in slate grey to bluish green shade, white margin, reverse cream to yellow shade; conidiophores thick walls, 43–60 x 1.8–2.2 µm; penicilli biverticillata; conidia elliptical when young, globose when matured, rough, 2.1–3 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

82. ***Penicillium*** **sp. 18** **(Plate 21, D-F)**

Synonyms: Nil.

Description: Colony floccose, in white colour, PDA becomes yellow, reverse yellow-brown shade; conidiophores unbranched, smooth-walled, 71–114.9 x 2.4–2.9 µm; penicilli monoverticillata; conidia globose, rough, 2–2.5 µm in diameter.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

83. ***Penicillium*** **sp. 19** **(Plate 21, G-I)**

Synonyms: Nil.

Description: Colony velvety, tough, in white to peach shade, silver colour exudates present, sulcations present, reverse yellowish-brown shade; conidiophores long, smooth-walled, with short branches; penicilli asymmetrica; conidia elliptical, 1.9–2.3 x 1.1–1.3 µm.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

84. ***Penicillium* sp. 20** **(Plate 21, J-L)**

Synonyms: Nil.

Description: Colony velvety to floccose, concentric rings present, in white to peach colour, reverse yellow shade; conidiophores simple, smooth-walled, 62.8–120.4 x 1.2–2.6 µm; penicilli monoverticillata; conidia globose, 2.3–2.5 µm in diameter.

Distribution: Isolated from Iringole Kavu.

85. ***Penicillium* sp. 21** **(Plate 22, A-C)**

Synonyms: Nil.

Description: Colony velvety to floccose, in white to bluish green colour, red colour exudates present, exudates are overgrown by secondary hyphae gives the nodular appearance, reverse yellow-brown shade; conidiophores long, smooth-walled, 78–189.4 x 3.5–4.8 µm; penicilli biverticillata; conidia globose, echinulate, 2.5–3.1 µm in diameter.

Distribution: Isolated from Poyilkavu.

86. ***Penicillium* sp. 22** **(Plate 22, D-F)**

Synonyms: Nil.

Description: Colony velvety to floccose, in slate grey colour, then yellow shade, white margin, yellow colour exudates present, exudates are overgrown by secondary hyphae gives the nodular appearance, reverse yellow shade; conidiophores long, smooth-walled, 113.2–191 x 2.9–3.1 µm; penicilli biverticillata; conidia globose, rough, echinulate, 3.5–4.7 µm in diameter.

Distribution: Isolated from Poyilkavu.

Genus: *Talaromyces* C.R. Benj.

87. ***Talaromyces aculeatus*** (Raper & Fennell) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.639, Fig; 163 (1949).

(Plate 22, G-I)

Synonyms: *Penicillium aculeatum* Raper & Fennell, Mycologia 40 (5): 535 (1948).

Description: Colony velvety to floccose, in celandine to artemisia green colour, white margin, reverse mineral red colour; conidiophores short, 34–50 x 2–2.4 µm; penicilli biverticillata; conidia globose, echinulate, 3–4 µm in diameter.

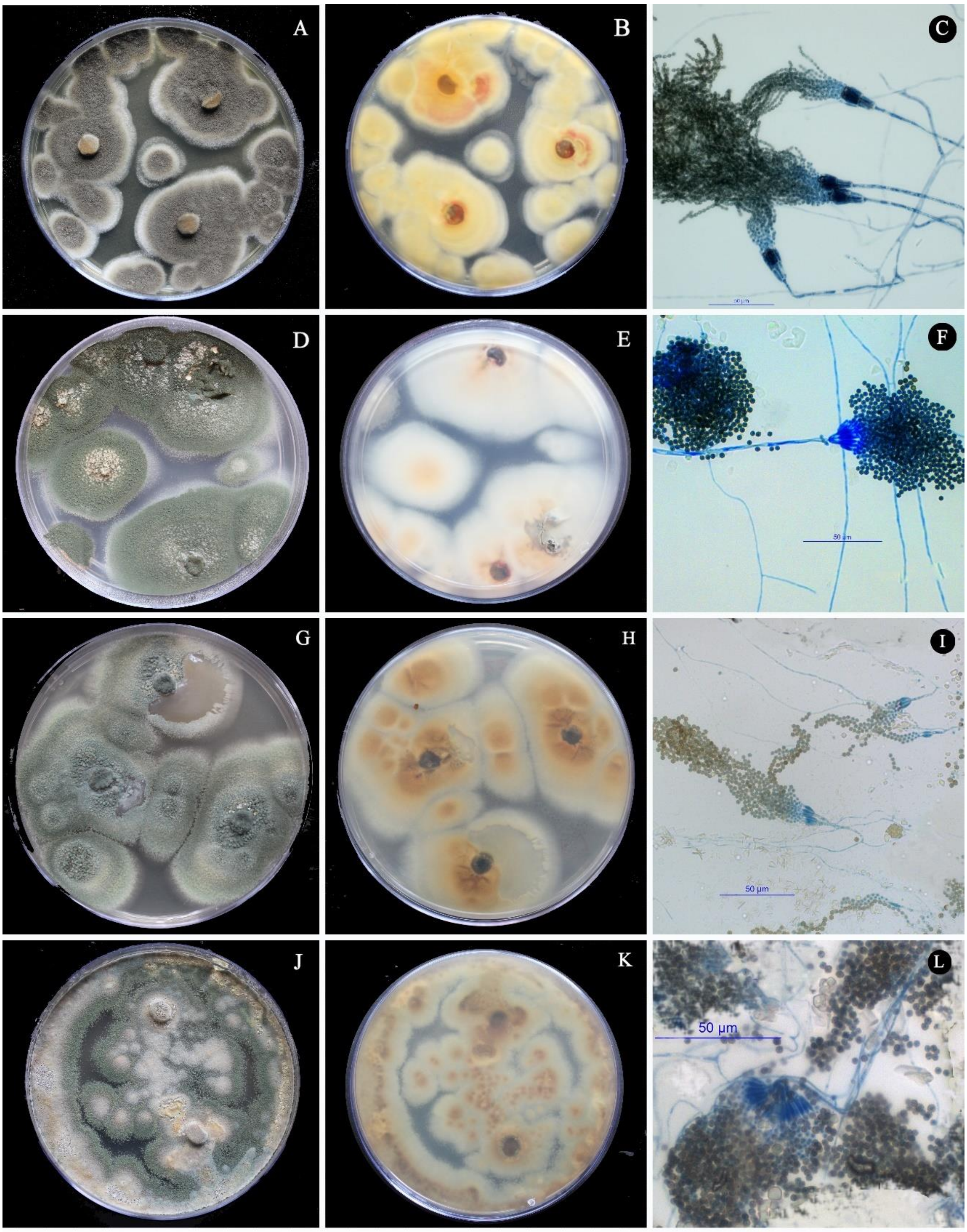

Plate 25. **A – C.** *Talaromyces variabilis*. **D – F.** *Talaromyces verruculosus*. **G – I.** *Talaromyces* sp. 1. **J – L.** *Talaromyces* sp. 2. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

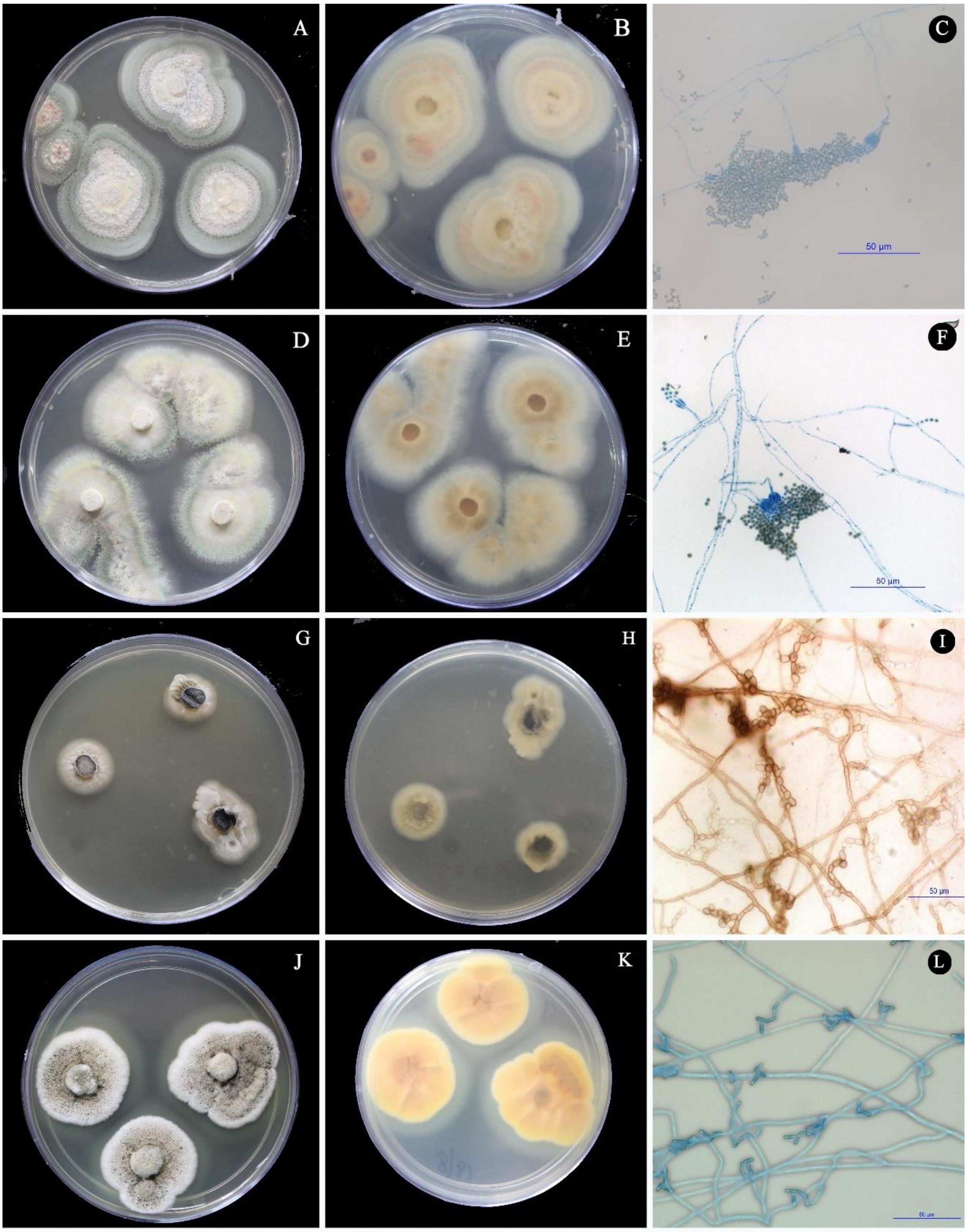

Plate 26. **A – C.** *Talaromyces* sp. 3. **D – F.** *Talaromyces* sp. 4. **G – I.** *Oidiodendron* sp. 1. **J – L.** *Geotrichum candidum.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

88. *Talaromyces atroroseus* N. Yilmaz, Frisvad, Houbraken & Samson, in Yilmaz et al., Polyphasic taxonomy of the genus *Talaromyces*, pp.221, Fig; 18 (2014).

(Plate 22, J-L)

Synonyms: Nil.

Description: Colony velvety to floccose, raised in the centre, bluish-green shade, red colour exudates present, PDA changes to red, reverse blood red colour; conidiophores simple, septate, 87–111 x 2.9–3.3 µm; penicilli biverticillata; conidia subglobose to elliptical, rough walled, 2.3–2.9 x 1.9–2.3 µm.

Distribution: Isolated from Iringole Kavu.

89. *Talaromyces brunneus* (Udagawa) Samson, Yilmaz & Frisvad, in Yilmaz et al., Polyphasic taxonomy of the genus *Talaromyces*, pp.229, Fig; 22 (2014).

(Plate 23, A-C)

Synonyms: *Penicillium brunneum* Udagawa, Journal of Agricultural Science Tokyo Nogyo Daigaku 5: 16 (1959).

Description: Colony velvety, raised at the centre, yellow to golden colour exudates present, in white to yellow colour, white margin, reverse yellowish-brown shade; conidiophores long, smooth-walled, 86–126 x 1.8–3.6 µm; penicilli biverticillata; conidia globose, slightly rough, 2.9–3.8 µm in diameter.

Distribution: Isolated from Iringole Kavu.

90. *Talaromyces diversus* (Raper & Fennell) Samson, Yilmaz & Frisvad, in Raper & Thom, A Manual of the Penicillia, pp.653, Fig; 165 (1949). **(Plate 23, D-F)**

Synonyms: *Penicillium diversum* Raper & Fennell, Mycologia 40 (5): 539 (1948).

Description: Colony velvety, colourless exudates present, first in white colour, then yellow-green to andover green colour, reverse yellow to brown shade; conidiophores smooth-walled, long, 137–212 x 2.3–2.6 µm; penicilli biverticillata; conidia subglobose, in chains, 2–2.4 x 1.7–2.1 µm.

Distribution: Isolated from Kollakal Thapovanam.

91. *Talaromyces duclauxii* (Delacr.) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.610, Fig; 158 (1949). **(Plate 23, G-I)**

Synonyms: *Penicillium duclauxii* Delacr., Bulletin de la Société Mycologique de France 7: 107 (1891).

Description: Colony velvety to funiculose, colourless exudates present, in yellow-green shade, reverse in yellow to brown colour; conidiophores long, smooth-walled, 160–313 x 2.2–2.9 µm; penicilli biverticillata; conidia elliptical to subglobose, rough, 2.6–2.9 x 2.4–2.7 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

92. ***Talaromyces flavus*** (Klöcker) Stolk & Samson, in Yilmaz et al., Polyphasic taxonomy of the genus *Talaromyces,* pp. 253, Fig; 38 (2014). **(Plate 23, J-L)**

Synonyms: *Gymnoascus flavus* Klöcker, Hedwigia 41: 80 (1902), *Talaromyces flavus* var. *flavus*, *Penicillium vermiculatum* P.A. Dang., Le Botaniste 10: 123 (1907), *Talaromyces vermiculatus* (P.A. Dang.) C.R. Benj., Mycologia 47: 684 (1955), *Eupenicillium vermiculatum* (P.A. Dang.) C. Ram & A. Ram, Brotéria Série Trimestral: Ciências Naturais 41 (1–2): 106 (1972), *Arachniotus indicus* Chattopadh. & C. Das Gupta, Transactions of the British Mycological Society 42 (1): 72 (1959), *Arachniotus indicus* var. *major* Chattopadh. & C. Das Gupta, Transactions of the British Mycological Society 42 (1): 73 (1959).

Description: Colony floccose, raised at the centre, in bright yellow colour, reverse orange to red colour; conidiophores smooth-walled, 22–30 x 1.4–2 µm; penicilli monoverticillata; conidia elliptical, smooth, 2.1–2.6 x 1.1–1.7 µm.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

93. ***Talaromyces funiculosus*** (Thom) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.616, Fig; 159 (1949). **(Plate 24, A-C)**

Synonyms: *Penicillium funiculosum* Thom, U.S.D.A. Bureau of Animal Industry Bulletin 118: 69 (1910), *Penicillium africanum* Doebelt, Ann. Mycol.: 316 (1909).

Description: Colony funiculose, tough, centre tufted, in slate olive colour, colourless exudates present, PDA colour changes to light red, reverse yellow to red shade; conidiophores long, smooth-walled, 105–256 x 2.8–3 µm; penicilli biverticillata; conidia globose, rough, in chains, 2–3 µm in diameter.

Distribution: Isolated from Iringole Kavu.

94. ***Talaromyces islandicus*** (Sopp) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.623, Fig; 160 (1949). **(Plate 24, D-F)**

Synonyms: *Penicillium islandicum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 161 (1912),

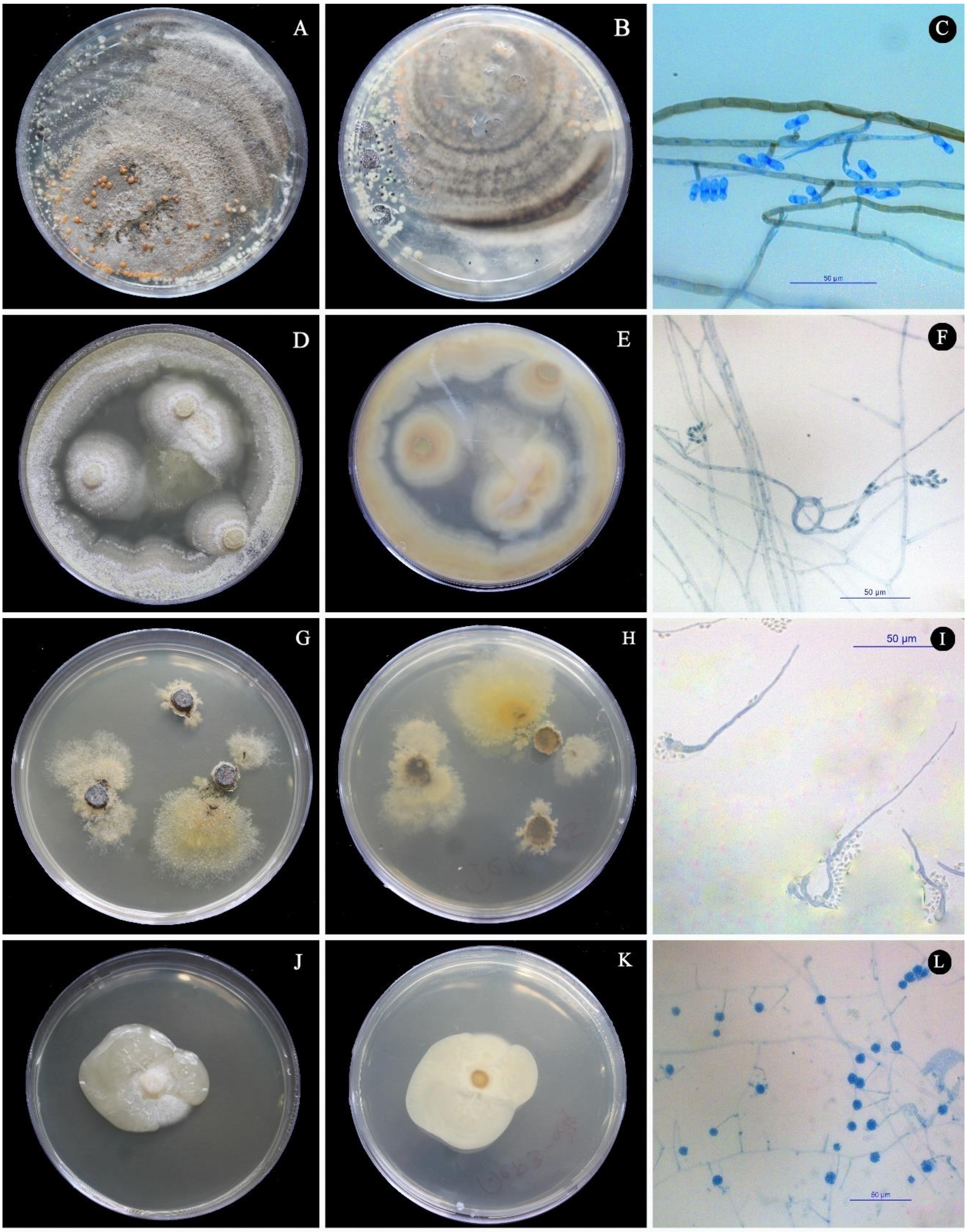

Plate 27. **A – C.** *Colletotrichum aotearoa.* **D – F.** *Colletotrichum* sp. 1. **G – I.** *Colletotrichum* sp. 2. **J – L.** *Furcasterigmium furcatum.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

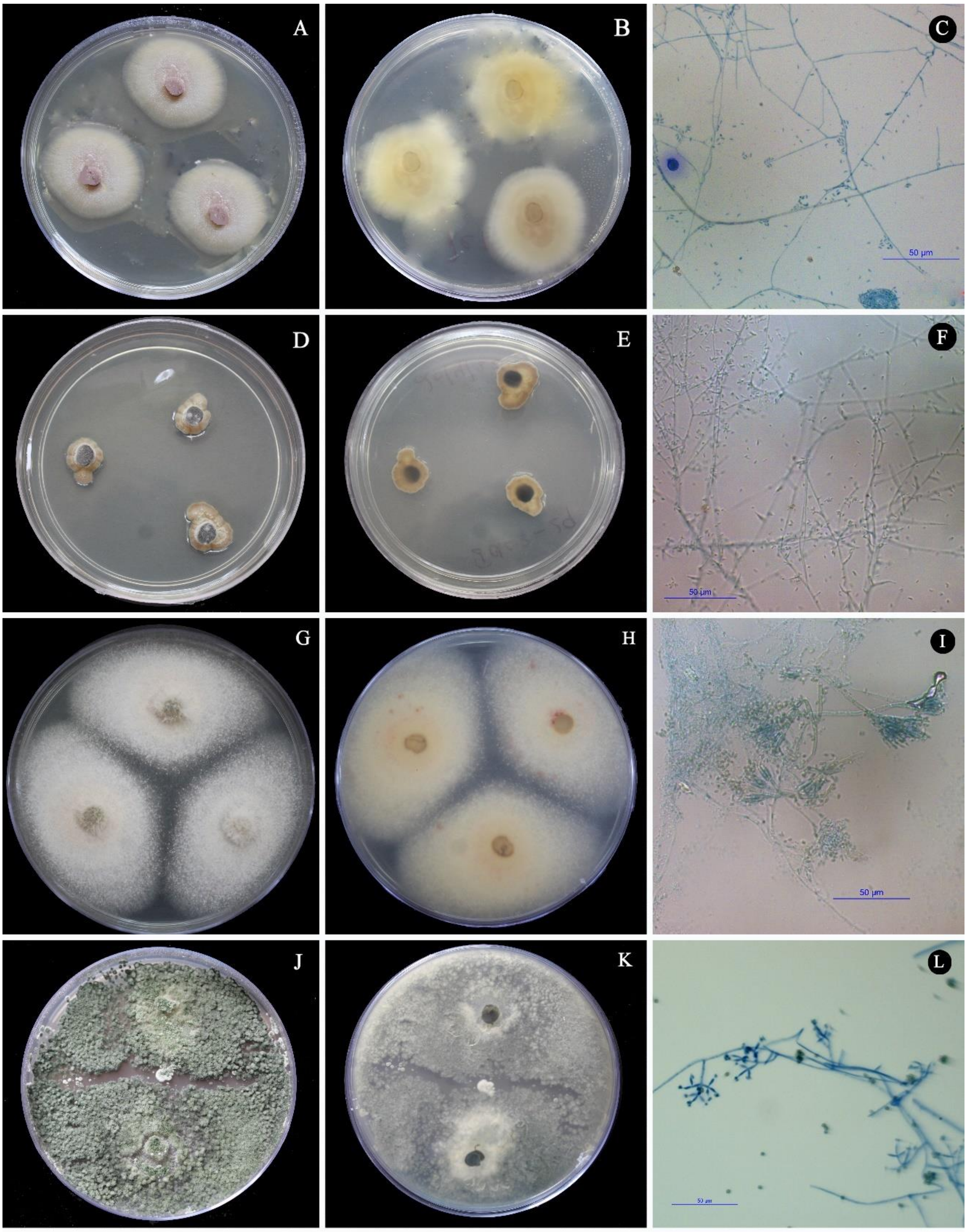

Plate 28. **A – C.** *Plectosphaerella cucumerina.* **D – F.** *Plectosphaerella* sp. 1. **G – I.** *Cordyceps farinosa*. **J – L.** *Trichoderma asperelloides.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Penicillium aurantioflammiferum C. Ramírez, A.T. Martínez & Berer., Mycopathologia 72 (1): 28 (1980), *Penicillium cirrhohepatis* Tsunoda.

Description: Colony velvety to funiculose, in yellow-green shade, wrinkled in radial pattern, brown colour exudates present, exudates are overgrown by secondary hyphae gives nodular appearance, reverse orange-brown shade; conidiophores short, smooth-walled, 30–75 x 2–2.4 µm; penicilli biverticillata; conidia elliptical, 3–4 x 2–2.4 µm.

Distribution: Isolated from Kollakal Thapovanam.

95. ***Talaromyces piceae*** (Raper & Fennell) Samson, N. Yilmaz, Houbraken, Spierenb., Seifert, Peterson, Varga & Frisvad, in Raper & Thom, A Manual of the Penicillia, pp.627, Fig; 161 (1949). **(Plate 24, G-I)**

Synonyms: *Penicillium piceae* Raper & Fennell, Mycologia 40 (5): 533 (1948), *Penicillium piceum* Raper & Fennell (1948), *Talaromyces piceus* (Raper & Fennell) Samson, N. Yilmaz, Houbraken, Spierenb., Seifert, Peterson, Varga & Frisvad (2011), *Penicillium ilerdanum* C. Ramírez & A.T. Martínez, Mycopathologia 72 (1): 32 (1980).

Description: Colony floccose, white to yellow colour mycelium, then pea green colour, centre raised, yellow-brown exudates present, reverse orange-yellow shade; conidiophores smooth-walled, 38–102 x 3–3.2 µm; penicilli biverticillata; conidia globose, rough, 2.8–3 µm in diameter.

Distribution: Isolated from Poyilkavu.

96. ***Talaromyces purpureogenus*** (Stoll) Samson, Yilmaz, Houbraken, Spierenburg, Seifert, Peterson, Varga & Frisvad, in Raper & Thom, A Manual of the Penicillia, pp.633, Fig; 162 (1949). **(Plate 24, J-L)**

Synonyms: *Penicillium purpureogenum* Stoll, Beiträge zur Morphologischen und Biologischen Charakteristik von Penicillium-Arten: 32 (1904), *Penicillium sanguineum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 175 (1912).

Description: Colony velvety to floccose, surface tufted, granular, red colour exudates present, yellow-green to greenish black shade, PDA changes to red, reverse blood red colour; conidiophores arising from substratum, 89–123 x 2.8–3.9 µm; penicilli biverticillata; conidia subglobose, apiculate, rough, 3–4 x 2.7–3 µm

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

97. ***Talaromyces variabilis*** (Sopp) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.642, Fig; 163 (1949). **(Plate 25, A-C)**

Synonyms: *Penicillium variabile* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 169 (1912).

Description: Colony velvety to granular, in slate olive colour, white margin, light red colour exudates present, reverse yellow to red shades; conidiophores smooth-walled, 98–107 x 2.8–3 µm; penicilli biverticillata, very long; conidia strongly elliptical, large conidia rough, 3–3.5 x 2–2.5 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

98. ***Talaromyces verruculosus*** (Peyronel) Samson, Yilmaz, Frisvad & Seifert, in Raper & Thom, A Manual of the Penicillia, pp.621, Fig; 160 (1949). **(Plate 25, D-F)**

Synonyms: *Penicillium verruculosum* Peyronel, I germi astmosferici dei fungi con micelio: 22 (1913).

Description: Colony floccose to funiculose, centre raised, white to yellow mycelium, then in jade green colour, colourless exudates present, reverse white to orange shade; conidiophores smooth-walled, 83–97 x 2.8–3.5 µm; penicilli biverticillata; conidia globose, echinulate, in dark green colour, 2.6–3.5 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

99. ***Talaromyces* sp. 1** **(Plate 25, G-I)**

Synonyms: Nil.

Description: Colony floccose to funiculose, centre raised, colourless exudates present, in yellowish green to slate green shade, white margin, reverse yellow to brown shade; conidiophores short, smooth-walled, 10–28 x 1.6–1.8 µm; penicilli irregular, monoverticillata; conidia globose, slightly echinulate, 2.4–3.2 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

100. ***Talaromyces* sp. 2** **(Plate 25, J-L)**

Synonyms: Nil.

Description: Colony velvety to funiculose, white to Green to mustard yellow colour, colourless exudates present, reverse cream to brown colour; conidiophores smooth-walled, 56–100 x 2.1–2.7 µm; penicilli biverticillata; conidia globose, rough, slightly echinulate, 2.2–3.1 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

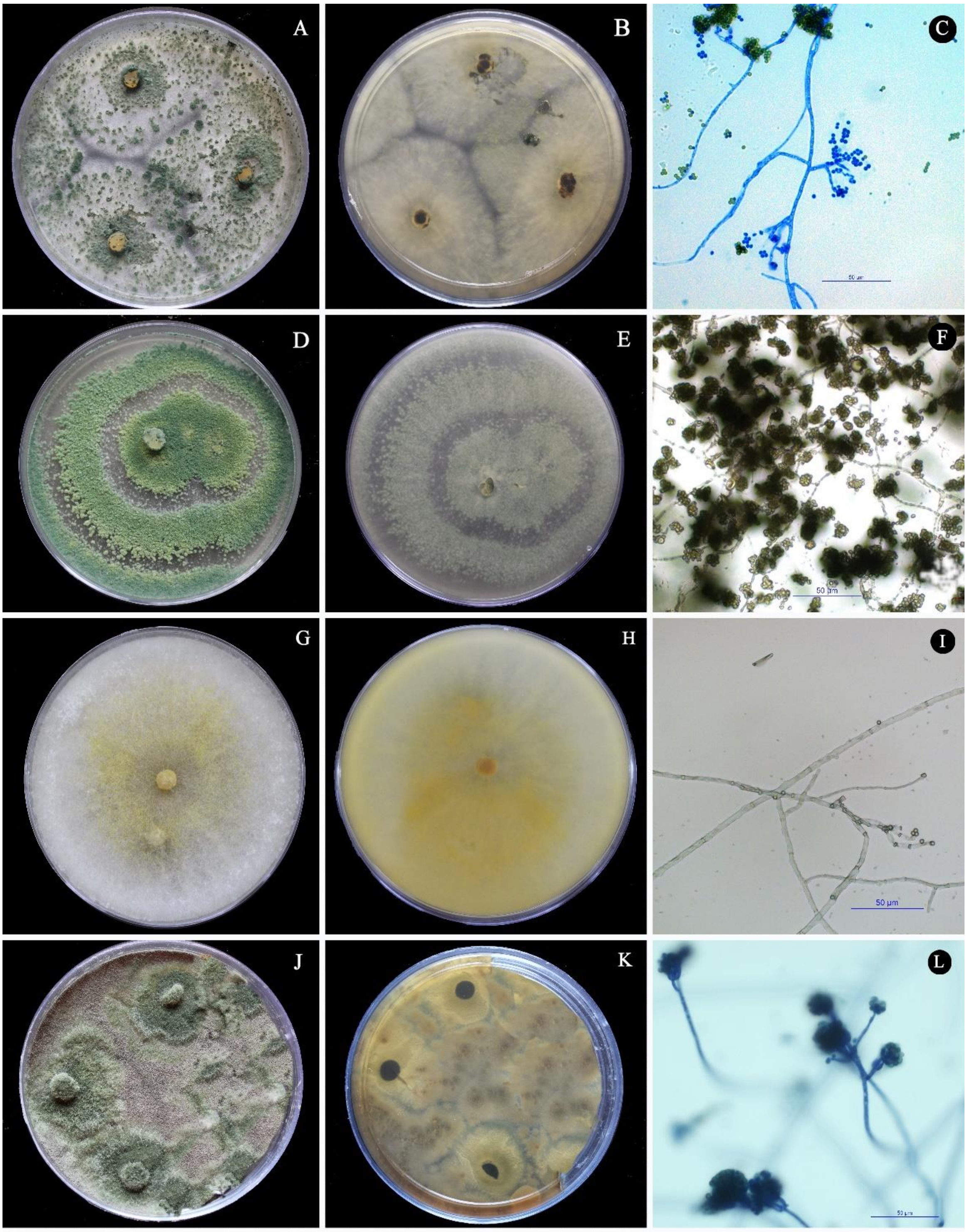

Plate 29. **A – C.** *Trichoderma hamatum.* **D – F.** *Trichoderma harzianum*. **G – I.** *Trichoderma spirale.* **J – L.** *Trichoderma virens.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

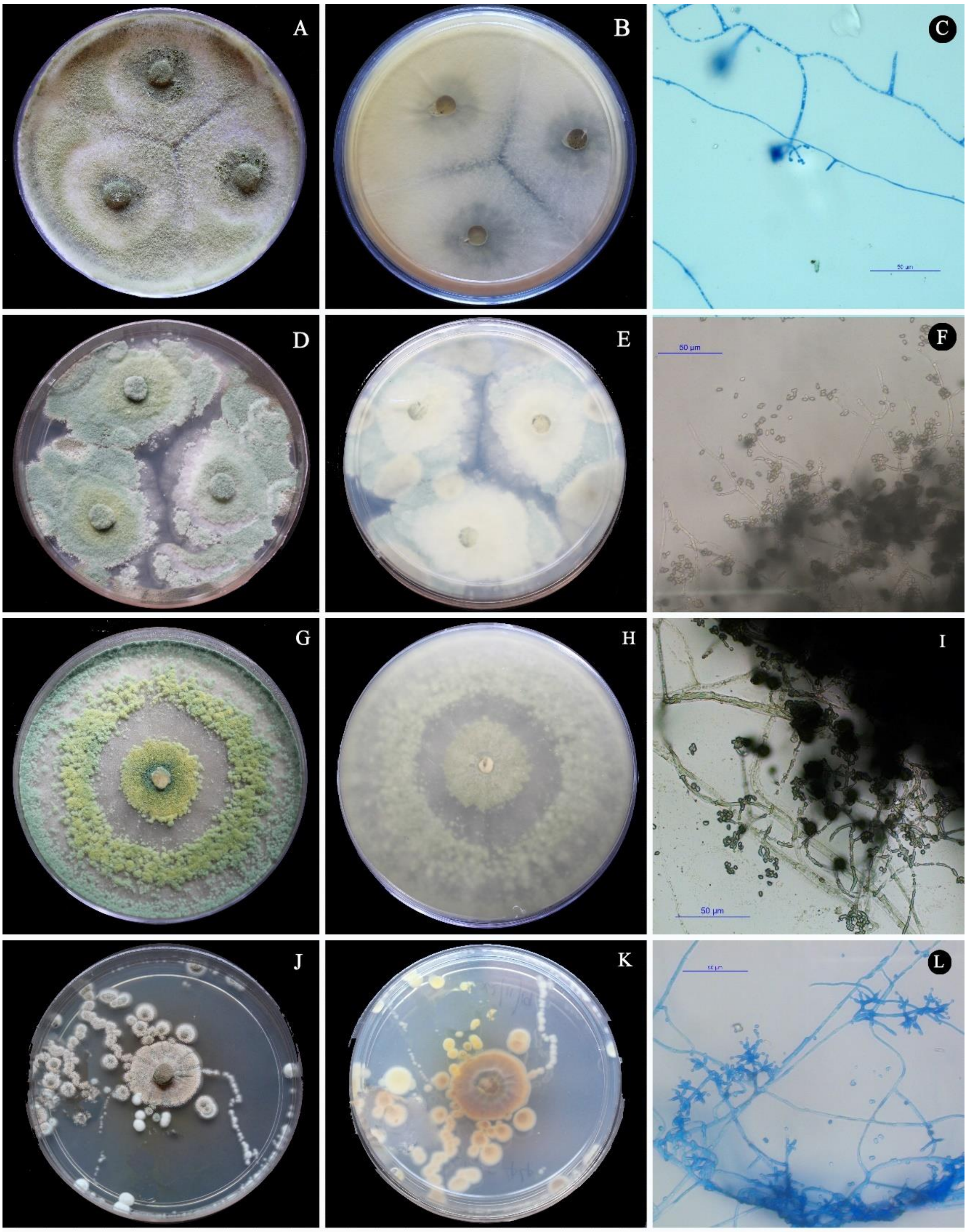

Plate 30. **A – C.** *Trichoderma viride.* **D – F.** *Trichoderma* sp. 1. **G – I.** *Trichoderma* sp. 2. **J – L.** *Trichoderma* sp. 3. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

101. ***Talaromyces* sp. 3** **(Plate 26, A-C)**

Synonyms: Nil.

Description: Colony velvety to funiculose, slimy colourless exudates present, concentric rings present, in white to green colour, reverse yellow to red shade; conidiophores short, smooth-walled, 39–62 x 1.4–1.7 µm; penicilli biverticillata; conidia elliptical, 2–2.7 x 1.7–2.1 µm.

Distribution: Isolated from Iringole Kavu.

102. ***Talaromyces* sp. 4** **(Plate 26, D-F)**

Synonyms: Nil.

Description: Colony velvety to funiculose, centre brown shade, then in yellow to green colour, white margin, reverse yellow-brown shade; conidiophores smooth-walled, 17–58 x 1–2 µm; penicilli monoverticillata; conidia globose, thick-walled, 2.5–2.9 µm in diameter.

Distribution: Isolated from Poyilkavu.

Class: Leotiomycetes

Order: Helotiales

Family: Myxotrichaceae

Genus: *Oidiodendron* Robak

103. ***Oidiodendron* sp. 1** **(Plate 26, G-I)**

Synonyms: Nil.

Description: Colony velvety, tough, sulcations present, in cream colour, middle black colour, reverse cream-black, shade; conidiophores long; conidia cylindrical to barrel-shaped, truncate ends, 4.7–8.1 x 4.3–5.7 µm.

Distribution: Isolated from Iringole Kavu.

Class: Saccharomycetes

Order: Saccharomycetales

Family: Dipodascaceae

Genus: *Geotrichum* Link

104. ***Geotrichum candidum*** Link, in Domsch & Gams, Compendium of Soil Fungi, pp. 348, Fig. 143 (1980). **(Plate 26, J-L)**

Synonyms: *Botrytis geotricha* Link, Caroli a Linné Species Plantarum exhibentes Plantas Rite Cognitas ad Genera Relatas 6 (1): 53 (1824), *Acrosporium candidum* (Link) Spreng., Caroli Linnaei systema vegetabilium 4 (1): 556 (1827), *Torula geotricha* (Link) Corda, Deutschlands Flora, Abt. III. Die Pilze Deutschlands 2 (8): 79 (1829), *Geotrichum versiforme* M. Moore, Annals of the Missouri Botanical Garden 21: 361 (1934), *Oidium lactis* Fresen., Beiträge zur Mykologie 1: 23 (1850), *Endomyces lactis* (Fresen.) Windisch, Beiträge zur Biologie der Pflanzen 28: 124 (1951), *Oosporoidea lactis* (Fresen.) Sumst., Mycologia 5 (2): 53 (1913), *Alysidium lactis* (Fresen.) Pound & Clem., Minnesota Botanical Studies 9: 650 (1896), *Oospora fragrans* var. *minuta* Berkhout, De schimmelgeslachten Monilia, Oidium, Oospora en Torula: 47 (1923), *Oospora lactis* var. *parasitica* F.J. Pritch. & Porte, Journal of Agricultural Research 24: 895 (1923), *Oospora lactis* (Fresen.) Sacc., Sylloge Fungorum 4: 15 (1886), *Geotrichum matalense* var. *chapmanii* A. Castellani, J. Trop. Med. Hyg.: 279 (1932), *Geotrichum javanense* Verona, Boll. Ist. Sup. Agrar. Pisa: 480 (1933), *Oidium matalense* Castell., Lect. Higher Fungi Rel. Hum. Path., R. Coll. Phys., London (1915), *Geotrichum matalense* (Castell.) Castell., J. Trop. Med. Hyg.: 278 (1932), *Pseudomonilia matalensis* (Castell.) C.W. Dodge, Medical mycology. Fungous diseases of men and other mammals: 295 (1935), *Pseudomycoderma matalense* (Castell.) Cif., Archiv für Protistenkunde 71: 436 (1930), *Oospora matalensis* (Castell.) Berkhout, De schimmelgeslachten Monilia, Oidium, Oospora en Torula: 46 (1923), *Mycoderma matalense* (Castell.) Brumpt, Précis de parasitologie: 1084 (1922), *Trichosporon matalense* (Castell.) Cif., Anais Soc. Biol. Pernambuco: 140 (1955), *Endomyces lactis* var. *matalensis* (Castell.) Windisch, Beiträge zur Biologie der Pflanzen 28: 123 (1951), *Oospora lactis* var. *exuberans* Stautz, Phytopathologische Zeitschrift 3: 189 (1931), *Geotrichum novakii* El-Masry & Zsolt, Acta Biol., Szeged. N. Ser.: 69 (1966), *Geotrichum redaelli* Negroni & I. Fisch. (1940), *Mycoderma malti-juniperini* Desm., Annales des Sciences Naturelles Botanique 10: 62 (1827), *Geotrichum malti-juniperini* (Desm.) F.P. Almeida, Anais da Faculdade de Medicina da Universidade de São Paulo 9: 78 (1933), *Geotrichum silvicola* Pimenta, G.S. Prasad, Lachance & C.A. Rosa, International Journal of Systematic and Evolutionary Microbiology 55 (1): 499 (2005), *Galactomyces candidus* de Hoog & M.T. Sm., Stud. Mycol. 50 (2): 504 (2004), *Monilia asteroides* Castell., J.

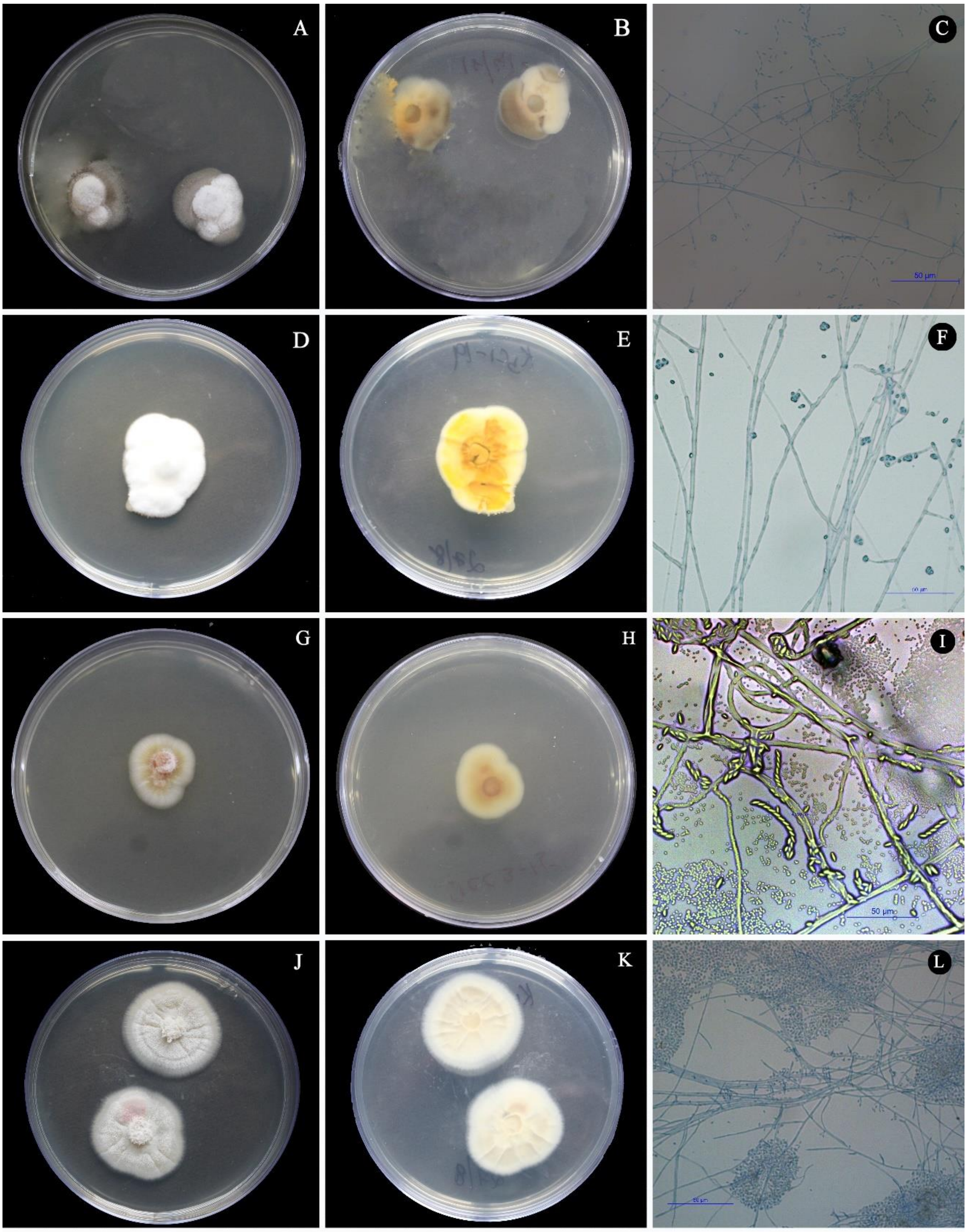

Plate 31. **A – C.** *Acremonium implicatum.* **D – F.** *Acremonium* sp. 1. **G – I.** *Acremonium* sp. 2. **J – L.** *Acremonium* sp. 3. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

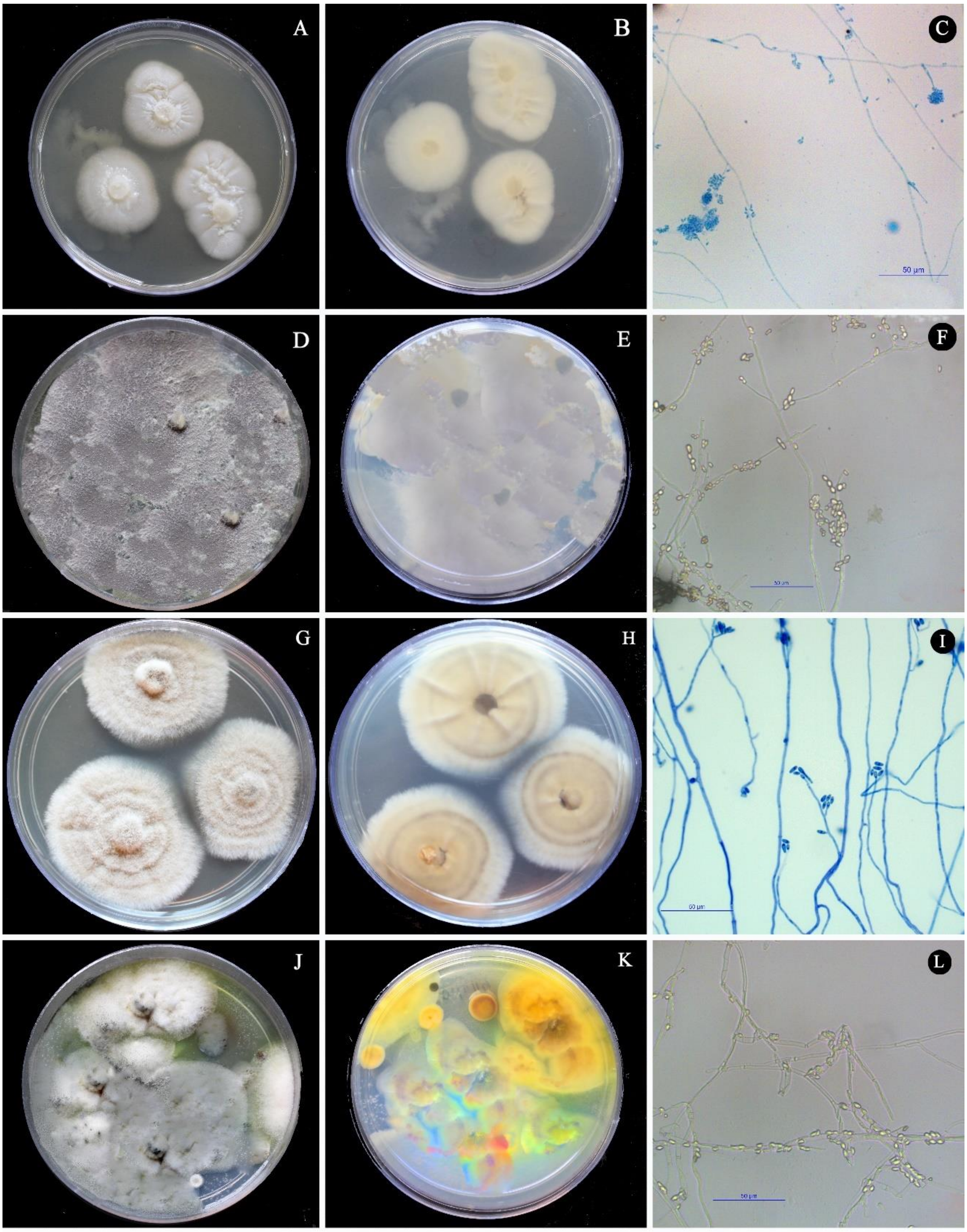

Plate 32. **A – C.** *Acremonium* sp. 4. **D – F.** *Gliomastix murorum*. **G – I.** *Gliomastix roseogrisea*. **J – L.** *Gliomastix* sp. 1. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Trop. Med. Hyg.: 307 (1914), *Oidium asteroides* (Castell.) Castell. & Chalm., Manual of Tropical Medicine: 1095 (1919), *Mycoderma asteroides* (Castell.) Brumpt, Précis de parasitologie: 1076 (1922), *Geotrichum asteroides* (Castell.) Basgal, Contribuçao ao Estudo des Blastomycoses Pulmonares: 48 (1931), *Oidium nubilum* Weigmann & A. Wolff, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 22: 668 (1909), *Oospora nubilum* (Weigmann & A. Wolff) Berkhout, De schimmelgeslachten Monilia, Oidium, Oospora en Torula: 50 (1923), *Oidium obtusum* Thüm., Mycoth. Univ. Cent. 3: no. 289 (1875), *Oospora lactis* var. *obtusa* (Thüm.) Sacc., Sylloge Fungorum 4: 15 (1886), *Oidium lactis* var. *luxurians* Riess, Klotzschii herbarium vivum mycologicum sistens fungorum per totam Germaniam crescentium collectionem perfectam. Cent. 19: no. 1885 (1854), *Oidium suaveolens* var. *minutum* Berkhout, Versl. Verg. Wis- Natuurk. Afd. KNAW: 119 (1923), *Oidium humi* P. Mazé, Annales de l'Institut Pasteur 24: 407 (1910), *Oospora humi* (P. Mazé) Berkhout, De schimmelgeslachten Monilia, Oidium, Oospora en Torula: 48 (1923), *Geotrichum bryndzae* Sulo, Laurenčík, Poláková, Minárik & E. Sláviková, International Journal of Systematic and Evolutionary Microbiology 59 (9): 2372 (2009), *Geotrichum redaellii* Negroni & I. Fisch., Revta Argent. Dermatosifil.: 147 (1940), *Galactomyces britannicus* Kwaśna & G.L. Bateman, Sydowia 60 (1): 77 (2008), *Galactomyces britannicum* Kwasna & G.L. Bateman (2008).

Description: Colony cottony, in white to black colour, reverse yellow to brown shade; hyphae dichotomously branched; conidia in chains, cylindrical, 5–7 x 2–2.5 µm.

Distribution: Isolated from Iringole Kavu.

Class: Sordariomycetes

Order: Glomerellales

Family: Glomerellaceae

Genus: *Colletotrichum* Corda

105. ***Colletotrichum aotearoa*** B. Weir & P.R. Johnst., in Weir et al., The *Colletotrichum gloeosporioides* species complex, pp. 139, Fig. 15,16 (2012).

(Plate 27, A-C)

Synonyms: Nil.

Description: Colony cottony, centre tufted, grey shade, shows an orange mass of spores produced from acervuli, reverse grey to orange shade, concentric rings present; conidia cylindrical, apex rounded, 10–17 x 5–5.4 µm.

Distribution: Isolated from Iringole Kavu.

106. *Colletotrichum* sp. 1 **(Plate 27, D-F)**

Synonyms: Nil.

Description: Colony velvety, centre tufted, in white to cream colour, reverse yellow to brown shade, concentric rings present; conidia cylindrical, apex rounded, 5.2–7.3 x 2.5–3 µm.

Distribution: Isolated from Kollakal Thapovanam.

107. *Colletotrichum* sp. 2 **(Plate 27, G-I)**

Synonyms: Nil.

Description: Colony velvety to floccose, in yellow cream shade, reverse yellow shade; conidia elliptical to fusiform, apex pointed, 3.8–4.5 x 1.5–2.7 µm.

Distribution: Isolated from Iringole Kavu.

Family: Plectosphaerellaceae

Genus: *Furcasterigmium* Giraldo López

108. *Furcasterigmium furcatum* (Gams) Giraldo López & Crous, in Domsch & Gams, Compendium of Soil Fungi, pp. 20, Fig. 7 (1980). **(Plate 27, J-L)**

Synonyms: *Acremonium furcatum* Moreau & V. Moreau ex W. Gams, Nova Hedwigia 18: 3 (1969).

Description: Colony velvety, slimy-like, colourless exudates present, reverse cream colour; philadies often in whorls; conidia in heads, elliptical to cylindrical, 2.7–3.8 x 1.4–2 µm.

Distribution: Isolated from Kollakal Thapovanam.

Genus: *Plectosphaerella* Kleb.

109. *Plectosphaerella cucumerina* (Lindf.) W. Gams, in Domsch & Gams, Compendium of Soil Fungi, pp. 660, Fig. 290 (1980). **(Plate 28, A-C)**

Synonyms: *Venturia cucumerina* Lindf., Meddelande Centralanst. Försksv. Jordbruksomr. Bot. Avd.: 7 (1919), *Monographella cucumerina* (Lindf.) Arx, Transactions of the British Mycological Society 83 (2): 374 (1984),

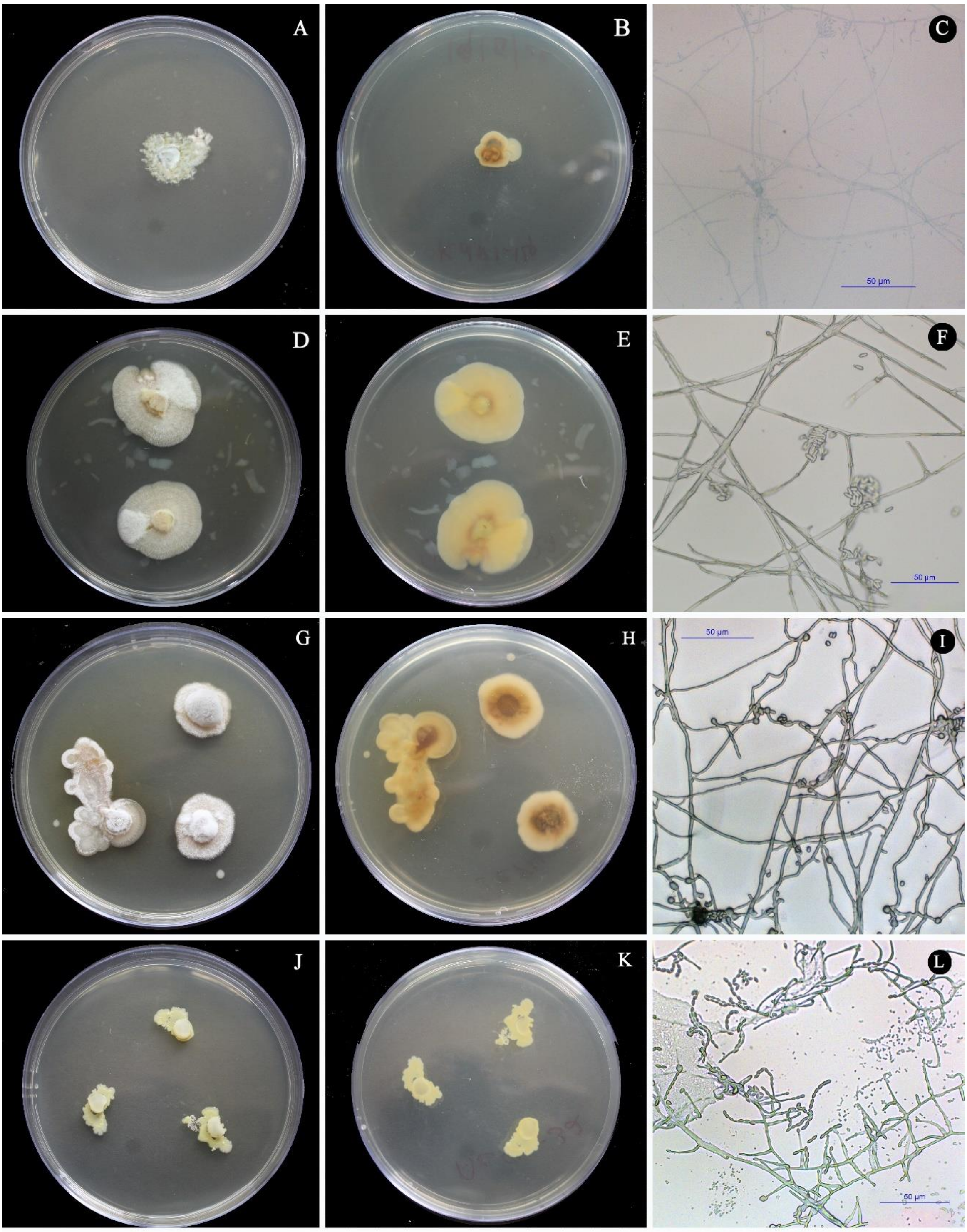

Plate 33. **A – C.** *Sarocladium gamsii.* **D – F.** *Sarocladium hominis*. **G – I.** *Sarocladium kiliense*. **J – L.** *Sarocladium* sp. 1. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

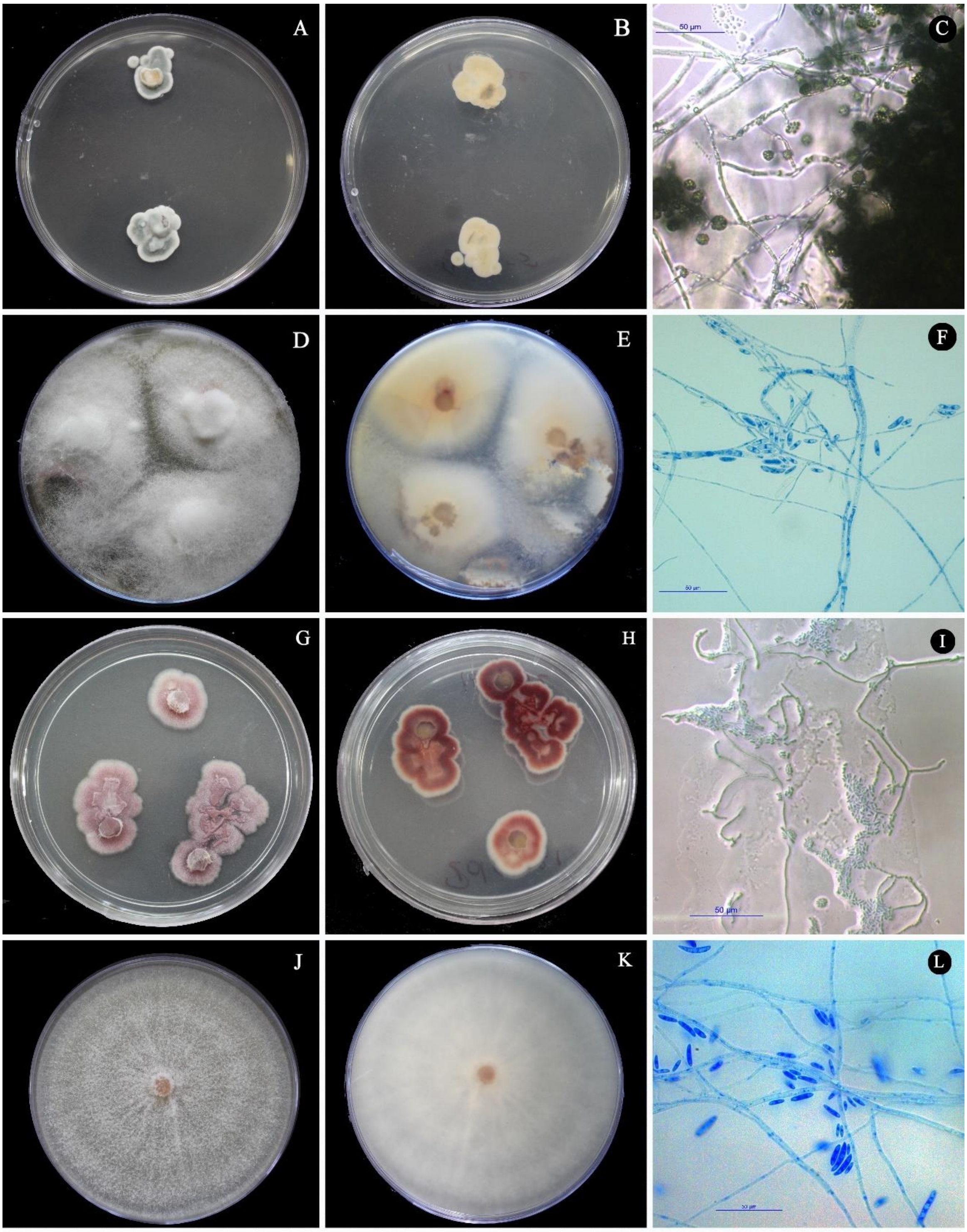

Plate 34. **A – C.** *Cosmospora butyri.* **D – F.** *Fusarium oxysporum*. **G – I.** *Fusarium tricinctum*. **J – L.** *Fusarium verticillioides.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Cephalosporium ciferrii Verona, Studio sulle cause microbiche che danneggiano la carta ed i libri: 30 (1939), *Cephalosporium tabacinum* J.F.H. Beyma, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 89: 240 (1933), *Fusarium tabacinum* (J.F.H. Beyma) W. Gams, Persoonia 5 (2): 179 (1968), *Plectosporium tabacinum* (J.F.H. Beyma) M.E. Palm, W. Gams & Nirenberg, Mycologia 87 (3): 399 (1995), *Microdochium tabacinum* (J.F.H. Beyma) Arx, Transactions of the British Mycological Society 83 (2): 374 (1984), *Plectosphaerella cucumeris* Kleb., Phytopathologische Zeitschrift 1: 43 (1929), *Micronectriella cucumeris* (Kleb.) C. Booth, The genus *Fusarium*: 39 (1971), *Septomyxa affinis* Wollenw., Fusaria Autographice Delineata 2: nos 643–644 (1924).

Description: Colony velvety, in cream to pinkish colour greenish, reverse cream to yellow to brown shade; phialides solitary, 6–44 x 1–2 µm; conidia slightly curved, one-septate, 3.5–9.2 x 1.5–2.3 µm.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

110. ***Plectosphaerella* sp. 1** **(Plate 28, D-F)**

Synonyms: Nil.

Description: Colony velvety to floccose, in brown shade, reverse brown colour; phialides solitary or in whorls, 5.9–13.4 x 1.3–2 µm; conidia cylindrical, one-septate, 2.1–4.3 x 1–1.4 µm.

Distribution: Isolated from Iringole Kavu.

Order: Hypocreales

Family: Cordycipitaceae

Genus: *Cordyceps* Fr.

111. ***Cordyceps farinosa*** (Holmsk.) Kepler, B. Shrestha & Spatafora, in Domsch & Gams, Compendium of Soil Fungi, pp. 527, Fig. 226 (1980). **(Plate 28, G-I)**

Synonyms: *Ramaria farinosa* Holmsk., Nye Saml. Kongel. Danske Vidensk. Selsk. Skr. 1: 299 (1781), *Paecilomyces farinosus* (Holmsk.) A.H.S. Br. & G. Sm., Transactions of the British Mycological Society 40 (1): 50 (1957), *Isaria farinosa* (Holmsk.) Fr., Systema Mycologicum 3: 271 (1832), *Spicaria farinosa* (Holmsk.) Vuill., Bulletin de la Société Mycologique de France 27: 76 (1911), *Clavaria farinosa* (Holmsk.) Dicks., Fasciculus plantarum cryptogamicarum Britanniae 2: 25 (1790), *Corynoides farinosa* (Holmsk.) Gray, A natural arrangement of British plants 1: 654 (1821), *Penicillium farinosum* (Holmsk.) Biourge, La Cellule 33: 102 (1923), *Isaria psychidae* Pole-Evans, Annales Mycologici 10 (3): 281 (1912), *Penicillium psychidae* (Pole-Evans) Biourge, La Cellule 33: 105 (1923).

Description: Colony floccose, white with pinkish shade, reverse yellow to orange shade, red colour dots present; conidiophores erect, tall, 104–276 µm long; phialides flask-shaped; conidia elliptical, 2.9–3.8 x 1.4–2.1 µm.

Distribution: Isolated from Iringole Kavu.

Family: Hypocreaceae

Genus: *Trichoderma* Pers.

112. ***Trichoderma asperelloides*** Samuels, in Samuels et al., *Trichoderma asperellum* sensu lato consists of two cryptic species, pp. 961, Fig. 7,8 (2010). **(Plate 28, J-L)**

Synonyms: Nil.

Description: Colony tufted, full of dark green pustules, reverse cream-grey shade; conidiophores slender, all branches terminate in a whorl of phialides; phialides flask-shaped; conidia in green mass, subglobose, 2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

113. ***Trichoderma hamatum*** (Bonord.) Bainier, in Domsch & Gams, Compendium of Soil Fungi, pp. 795, Fig. 352 (1980). **(Plate 29, A-C)**

Synonyms: *Verticillium hamatum* Bonord., Handbuch der allgemeinen Mykologie: 97 (1851), *Pachybasium hamatum* (Bonord.) Sacc., Revue Mycologique Toulouse 7: 161 (1885), *Phymatotrichum hamatum* (Bonord.) Oudem., Nederlandsch Kruidkundig Archief 2 (3): 908 (1903), *Monosporium ellipticum* Dasz., Bull. Soc. Bot. Genève 4: 307 (1912).

Description: Colony velvety, white mycelium, with green pustules, reverse cream to yellow shade; conidiophores long, short side branches, sterile hyphal elongations present; phialides broad; conidia in green mass, short-cylindrical, 3.5–4 x 1.9–2.6 µm.

Distribution: Isolated from Iringole Kavu.

114. ***Trichoderma harzianum*** Rifai, in Domsch & Gams, Compendium of Soil Fungi, pp. 797, Fig. 353 (1980). **(Plate 29, D-F)**

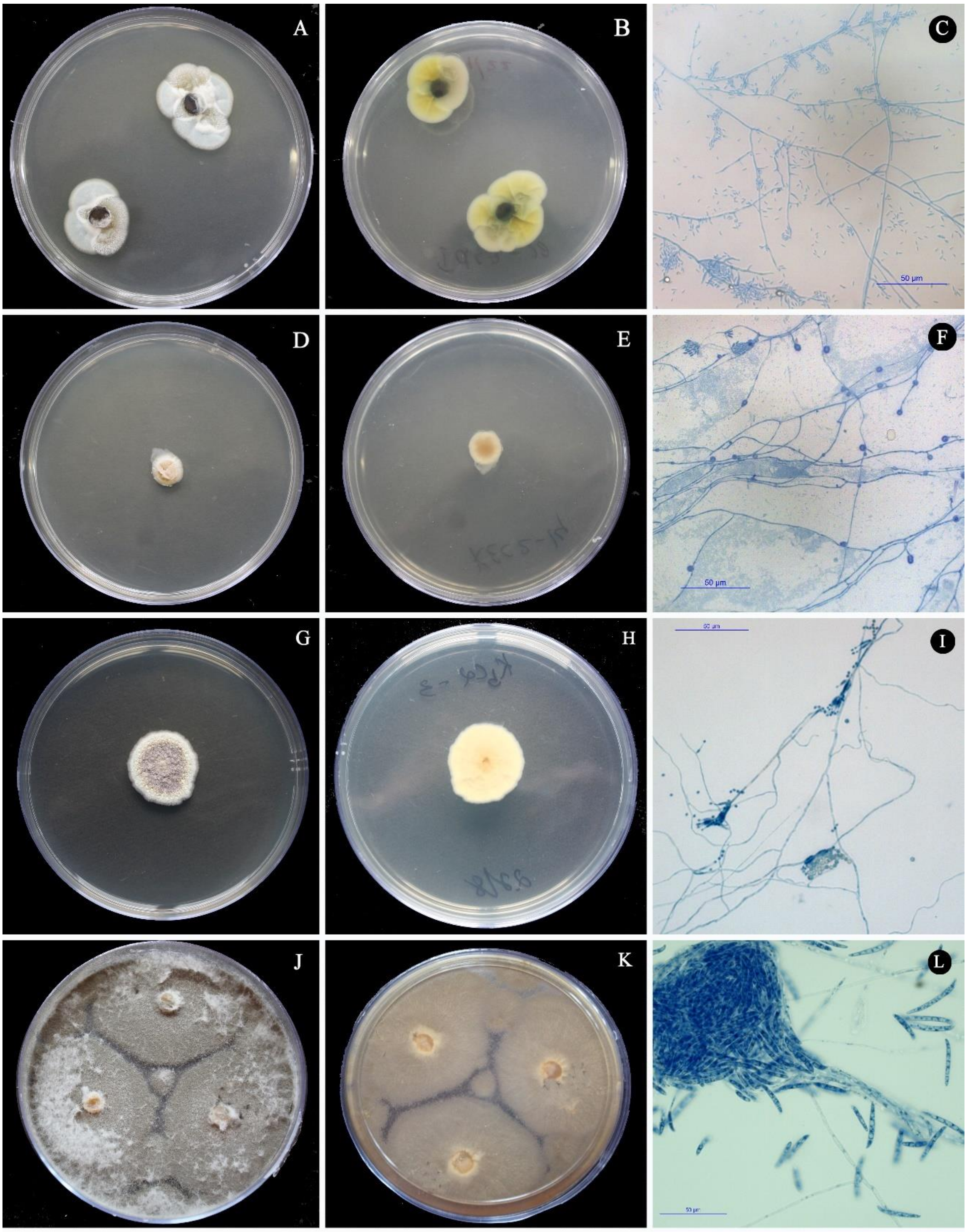

Plate 35. **A – C.** *Fusarium* sp. 1. **D – F.** *Fusarium* sp. 2. **G – I.** *Mariannaea* sp. 1. **J – L.** *Neocosmospora solani.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

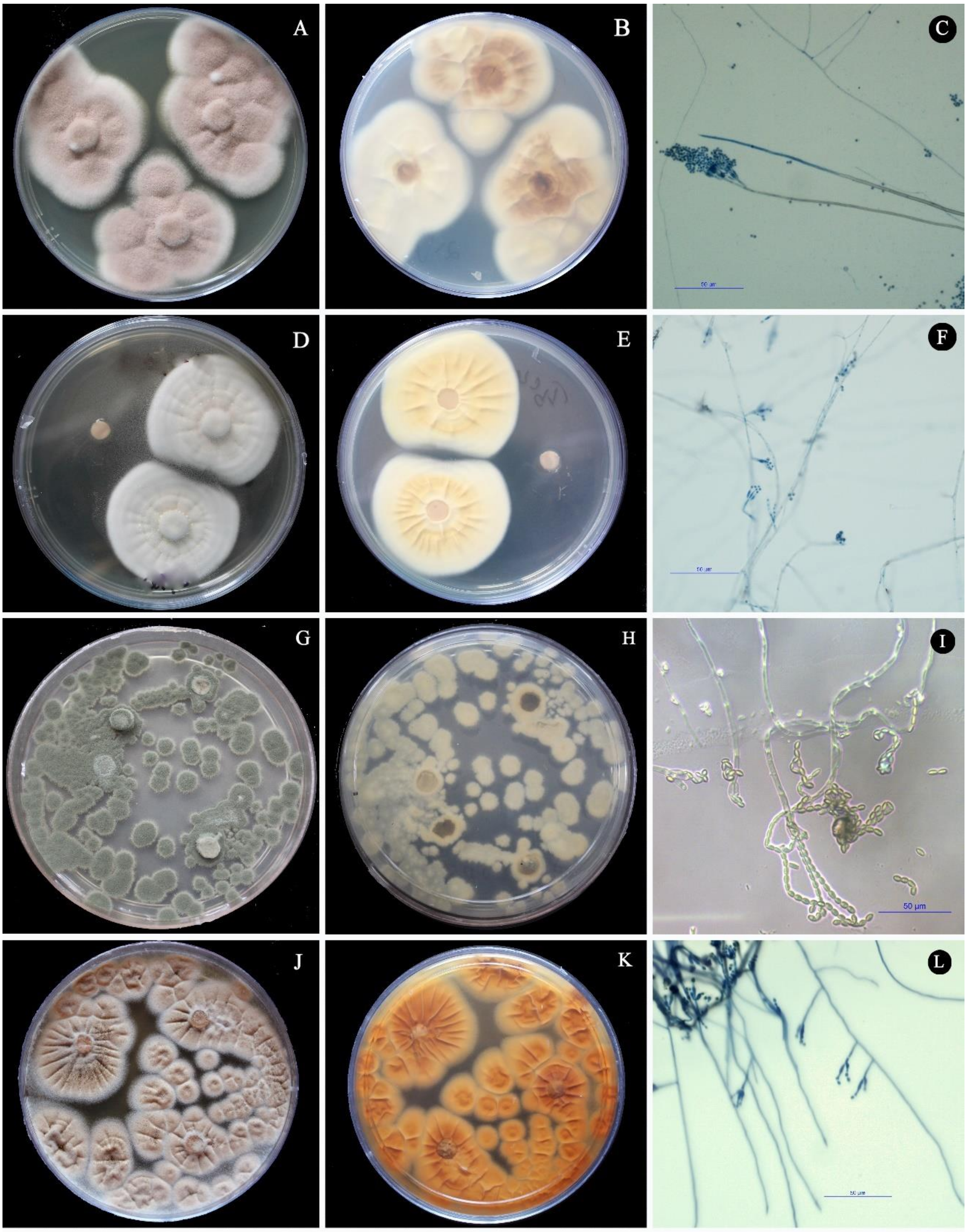

Plate 36. **A – C.** *Purpureocillium lilacinum.* **D – F.** *Purpureocillium lilacinum* – natural mutant. **G – I.** *Cephalotrichum asperulum.* **J – L.** *Microascus atrogriseus.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Synonyms: *Sporotrichum narcissi* Tochinai & Shimada, Trans. Sapporo nat. Hist. Soc.: 124 (1930), *Trichoderma narcissi* (Tochinai & Shimada) Tochinai & Shimada, Trans. Sapporo nat. Hist. Soc.: 24 (1931), *Trichoderma lignorum* var. *narcissi* (Tochinai & Shimada) Pidopl., Gribnaja Flora Grubych Kormov [Fungus flora of coarse fodder]: 182 (1953), *Trichoderma nunbergii* Szilvinyi, ZentBl. Bakt. ParasitKde, Abt. 2: 135 (1932).

Description: Colony tufted, white mycelium, with bright yellow to green pustules, reverse uncoloured; conidiophores long; phialides not crowded, disposed in number of 3 or more; conidia in green mass, short-obovoid, 2.9–3.2 x 2.5–2.8 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

115. ***Trichoderma spirale*** Bissett, in Gams and Bissett, Morphology and identification of Trichoderma, pp. 21 (2002). **(Plate 29, G-I)**

Synonyms: Nil.

Description: Colony cottony, white mycelium, with white to yellow pustules, reverse yellow shade; conidiophores long, less branched; phialides not crowded; conidia oblong, 2.9–3.8 x 2.2–2.7 µm.

Distribution: Isolated from Iringole Kavu.

116. ***Trichoderma virens*** (J.H. Mill., Giddens & A.A. Foster) Arx, in Domsch & Gams, Compendium of Soil Fungi, pp. 375, Fig. 153 (1980). **(Plate 29, J-L)**

Synonyms: *Gliocladium virens* J.H. Mill., Giddens & A.A. Foster, Mycologia 49 (6): 792 (1957), *Gliocladium flavofuscum* J.H. Mill., Giddens & A.A. Foster, Mycologia 49 (6): 793 (1957), *Trichoderma flavofuscum* (J.H. Mill., Giddens & A.A. Foster) Bissett, Canad. J. Bot. 69 (11): 2385 (1992), *Hypocrea virens* P. Chaverri, Samuels & E.L. Stewart, Mycologia 93: 1120 (2001).

Description: Colony tufted, white mycelium, with grey to green pustules, reverse yellow to brown shade; conidiophores long, short side branches; phialides crowded in the tip, in whorls, ampulliform; conidia green, in heads, short-ellipsoidal, 4–5 x 3–4 µm.

Distribution: Isolated from Kollakal Thapovanam.

117. ***Trichoderma viride*** Pers., in Domsch & Gams, Compendium of Soil Fungi, pp. 803, Fig. 356 (1980). **(Plate 30, A-C)**

Synonyms: *Pyrenium lignorum* var. *vulgare* Tode, Fungi Mecklenburgenses Selecti 1: 33 (1790), *Sphaeria rufa* Pers., Ann. Bot. (Usteri) 15: 20 (1795), *Hypocrea rufa* (Pers.) Fr., Summa vegetabilium Scandinaviae 2: 383 (1849), *Hypocrea rufa* subsp. *rufa*, *Discosphaera rufa* (Pers.) Dumort., Commentationes botanicae: 91 (1822), *Trichoderma glaucum* E.V. Abbott, Iowa State College Journal of Science: 27 (1927), *Fusisporium arundinis* Corda, Icones fungorum hucusque cognitorum 1: 11, tab. 2, fig. 163 (1837), *Fusarium arundinis* (Corda) Sacc., Sylloge Fungorum 4: 724 (1886), *Pyrenium lignorum* Tode, Fungi Mecklenburgenses Selecti 1: 33 (1790), *Trichoderma lignorum* (Tode) Harz, Bulletin de la Société Impériale des Naturalistes de Moscou 44: 116 (1871), *Trichoderma viride* Schumach., Enumeratio Plantarum, in Partibus Sællandiae Septentrionalis et Orientalis Crescentium 2: 235 (1803).

Description: Colony cottony, white mycelium, with yellow to green pustules, dark green colour exudates present, reverse cream to yellow to green shade; conidiophores pyramidally branched; phialides 2–4, slender; conidia globose to subglobose, 2.5–3.2 µm in diameter.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

118. *Trichoderma* sp. 1 **(Plate 30, D-F)**

Synonyms: Nil.

Description: Colony floccose, white mycelium, with pustules in green shades, reverse cream to white colour; conidiophores long; phialides not crowded, flask-shaped; conidia cylindrical to ellipsoidal, 3.8–4.9 x 2.2–2.8 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

119. *Trichoderma* sp. 2 **(Plate 30, G-I)**

Synonyms: Nil.

Description: Colony cottony, white mycelium, pustules in green to blue-green shades, dark green exudates present, PDA turns to green, reverse cream to white colour; conidiophores long, branched; phialides crowded at the tip, flask-shaped; conidia obovoid, 3.8–4.9 x 2.2–2.8 µm

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

120. *Trichoderma* sp. 3 **(Plate 30, J-L)**

Synonyms: Nil.

Description: Colony velvety, in white to brown colour, radial furrows and concentric rings present, reverse yellow to dark brown shade; conidiophores short, pyramidal branching; phialides 3–5, flask-shaped; conidia subglobose to oval, 3.5–3.9 x 2.3–2.5 µm.

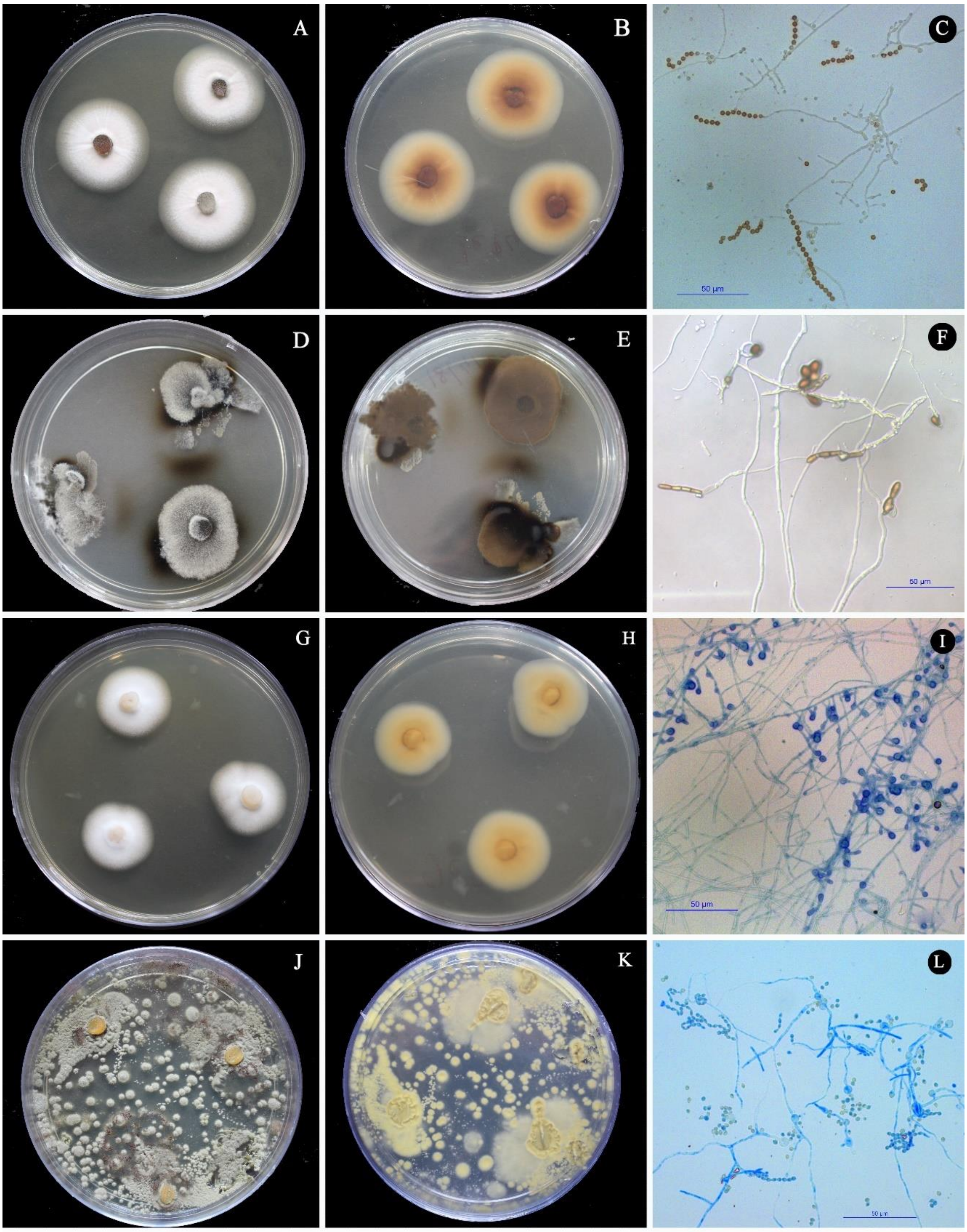

Plate 37. **A – C.** *Microascus* sp. 1. **D – F.** *Scedosporium apiospermum*. **G – I.** *Scedosporium* sp. 1. **J – L.** *Scopulariopsis asperula.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

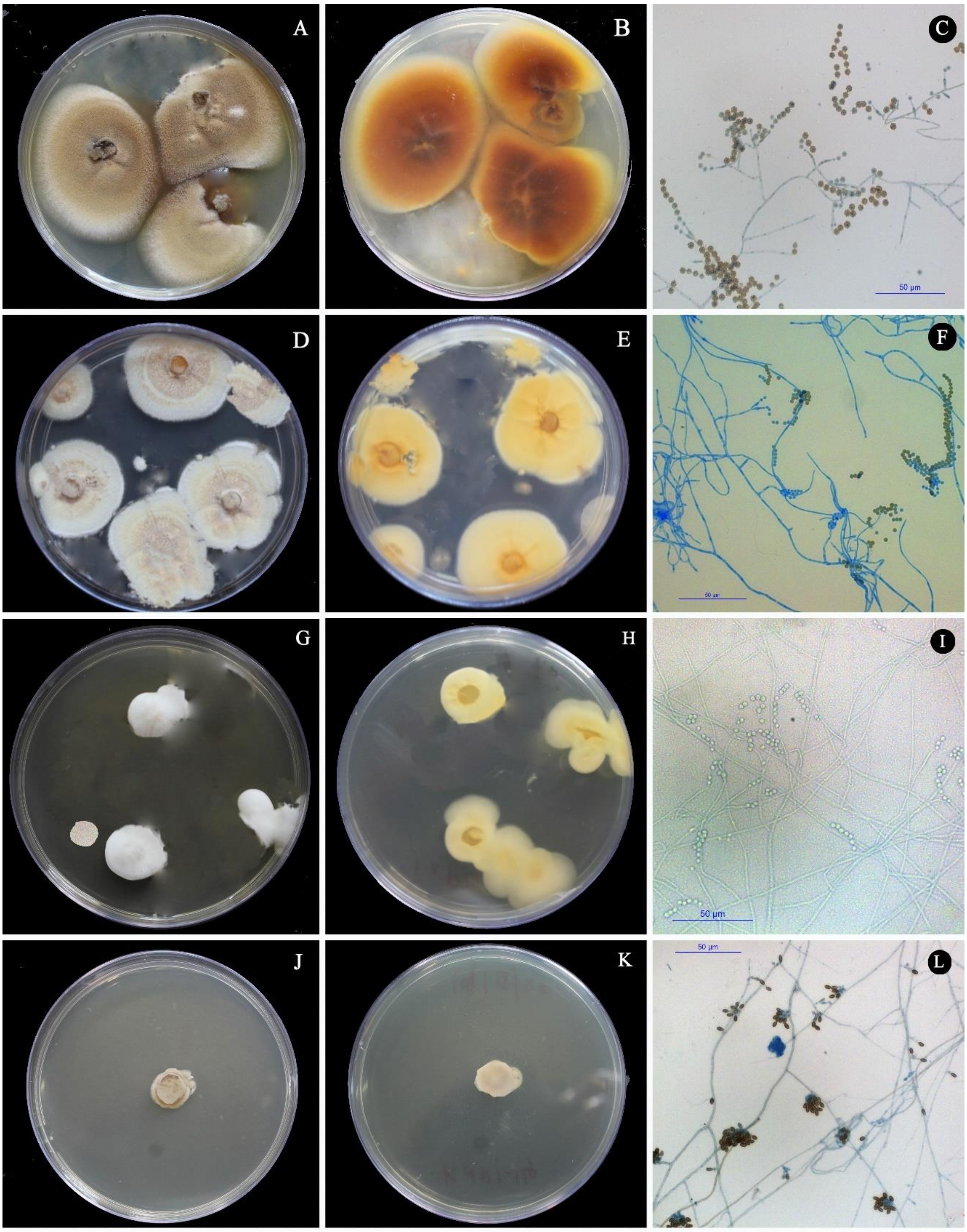

Plate 38. **A – C.** *Scopulariopsis brevicaulis.* **D – F.** *Scopulariopsis candida.* **G – I.** *Scopulariopsis sp. 1.* **J – L.** *Wardomyces inflatus.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

Distribution: Isolated from Iringole Kavu.

Genus: *Acremonium* Link

121. ***Acremonium implicatum*** (J.C. Gilman & E.V. Abbott) W. Gams, in Gilman, A Manual of Soil Fungi, pp. 208 (1956). (**Plate 31, A-C)**

Synonyms: *Monilia implicata* J.C. Gilman & E.V. Abbott, Iowa State College Journal of Science 1 (3): 269 (1927), *Sagrahamala implicata* (J.C. Gilman & E.V. Abbott) Subram., Kavaka 5: 98 (1978), *Sarocladium implicatum* (J.C. Gilman & E.V. Abbott) Giraldo, Gené & Guarro, Persoonia 34: 16 (2015), *Fusidium terricola* J.H. Mill., Giddens & A.A. Foster, Mycologia 49 (6): 796 (1957), *Acremonium terricola* (J.H. Mill., Giddens & A.A. Foster) W. Gams, Cephalosporium-artige Schimmelpilze: 67 (1971), *Paecilomyces terricola* (J.H. Mill., Giddens & A.A. Foster) Onions & G.L. Barron, Mycological Papers 107: 10 (1967), *Sagrahamala terricola* (J.H. Mill., Giddens & A.A. Foster) Subram. & Pushkaran, Kavaka 3: 89 (1975), *Sarocladium terricola* (J.H. Mill., Giddens & A.A. Foster) A. Giraldo, Gené & Guarro, Persoonia 34: 22 (2015).

Description: Colony cottony to floccose, white, reverse yellow shade; conidiophores crowded in mycelium, tapering towards apex, borne as short branches, 17–36 µm long; conidia in chains, lens-shaped, 3.7–4.9 x 1–1.3 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

122. ***Acremonium* sp. 1** **(Plate 31, D-F)**

Synonyms: Nil.

Description: Colony cottony, white, PDA changes to yellow, reverse bright yellow shade; conidiophores erect, tapering towards apex, borne as short branches, 16–22 µm long; conidia in slimy heads, oval, 2–3 x 1–2.1 µm.

Distribution: Isolated from Poyilkavu.

123. ***Acremonium* sp. 2** **(Plate 31, G-I)**

Synonyms: Nil.

Description: Colony velvety, in cream to pinkish shade, reverse yellow shade; conidiophores long, tapering towards apex; conidia in slimy heads and chains, elliptical, 5.1–7.8 x 2–3.7 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

124. ***Acremonium* sp. 3** **(Plate 31, J-L)**

Synonyms: Nil.

Description: Colony velvety to funiculose, in white to pinkish shade, sulcations present, reverse cream colour; conidiophores borne as short branches, abundant, 5–18 µm long; conidia in loose heads, abundant, oval to elliptical, 2–4 x 2–2.2 µm.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

125. ***Acremonium* sp. 4** **(Plate 32, A-C)**

Synonyms: Nil.

Description: Colony velvety, wet-like, in cream to pinkish shade, sulcations present, reverse cream colour; conidiophores borne as short branches, up to 27 µm long; conidia in slimy heads, cylindrical, 2.6–3.4 x 1.4–1.7 µm.

Distribution: Isolated from Kollakal Thapovanam.

Genus: *Gliomastix* Guég.

126. ***Gliomastix murorum*** (Corda) S. Hughes, in Domsch & Gams, Compendium of Soil Fungi, pp. 25, Fig. 11 (1980). **(Plate 32, D-F)**

Synonyms: *Torula murorum* Corda, Icones fungorum hucusque cognitorum 2: 9, t. 9:39 (1838), *Acremonium murorum* (Corda) W. Gams: 84 (1971), *Torula cephalosporioides* J.F.H. Beyma, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 96: 425 (1937), *Torula convoluta* Harz, Bulletin de la Société Impériale des Naturalistes de Moscou 44: 134 (1871), *Gliomastix convoluta* (Harz) E.W. Mason, Mycological Papers 5: 117 (1941), *Graphium malorum* Kidd & Beaumont, Transactions of the British Mycological Society 10 (1–2): 113 (1924), *Periconia felina* Marchal, Bulletin de la Société Botanique Belgique: 141 (1895), *Gliomastix convoluta* var. *felina* (Marchal) Mason, Mycological Papers 5: 118 (1941), *Gliomastix murorum* var. *felina* (Marchal) S. Hughes, Canadian Journal of Botany 36 (6): 769 (1958), *Gliomastix felina* (Marchal) Hammill, Mycologia 73: 231 (1981), *Acremonium felinum* (Marchal) Kiyuna, An, Kigawa & Sugiy., Mycoscience 52 (1): 13 (2011).

Description: Colony floccose, surface tufted, in white to black colour, reverse brown colour; phialides from hyphae; conidia elliptical to subglobose, warted, in chains, 4–5.8 x 2.5–3.4 µm.

Distribution: Isolated from Iringole Kavu.

127. ***Gliomastix roseogrisea*** (S.B. Saksena) Summerb., in Gilman, A Manual of Soil Fungi, pp. 211 (1956). **(Plate 32, G-I)**

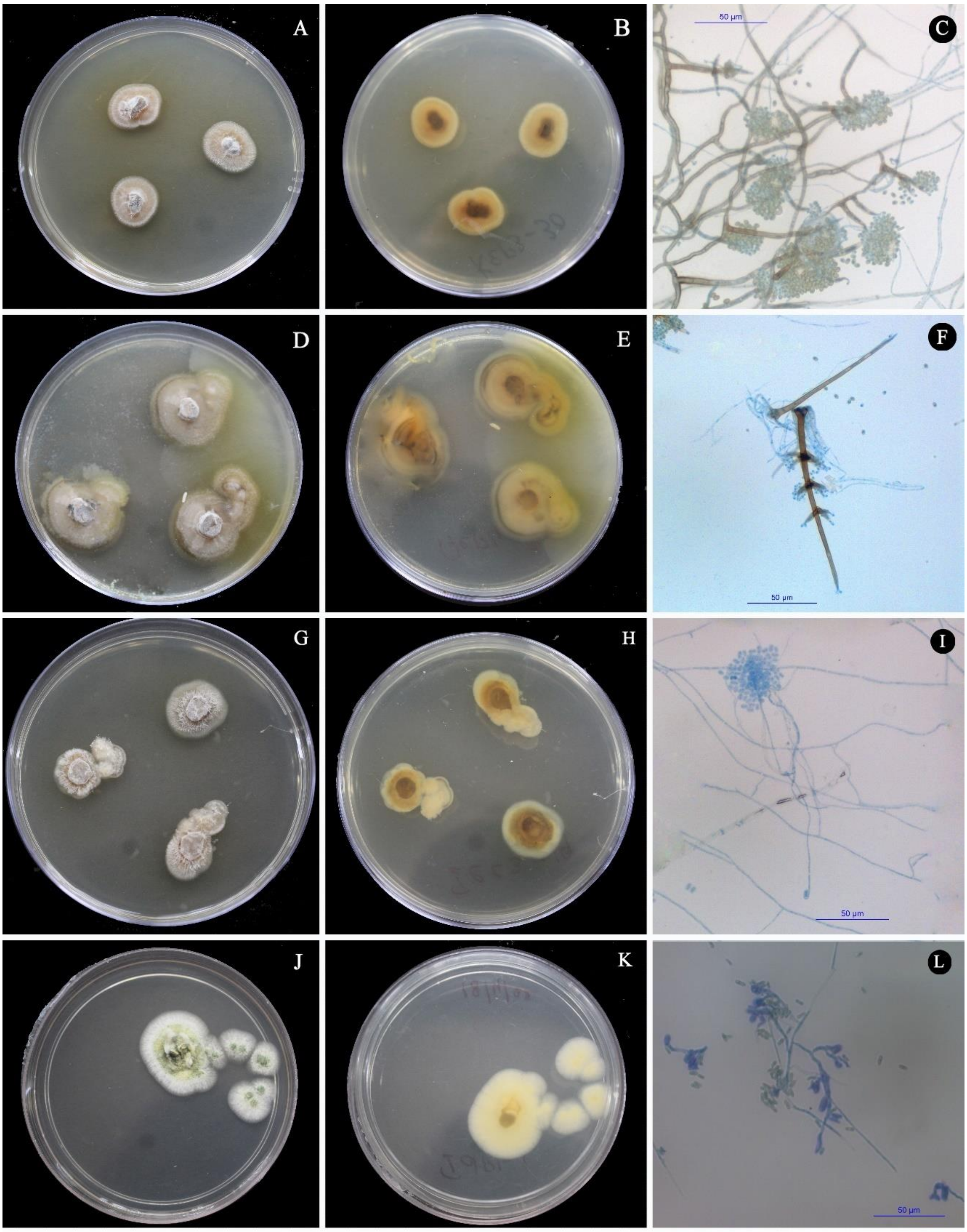

Plate 39. **A – C.** *Chloridium guttiferum.* **D – F.** *Chloridium* sp. 1. **G – I.** *Chloridium* sp. 2. **J – L.** *Sirococcus tsugae.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I, L.** Microscopic view with conidiophore and conidia.

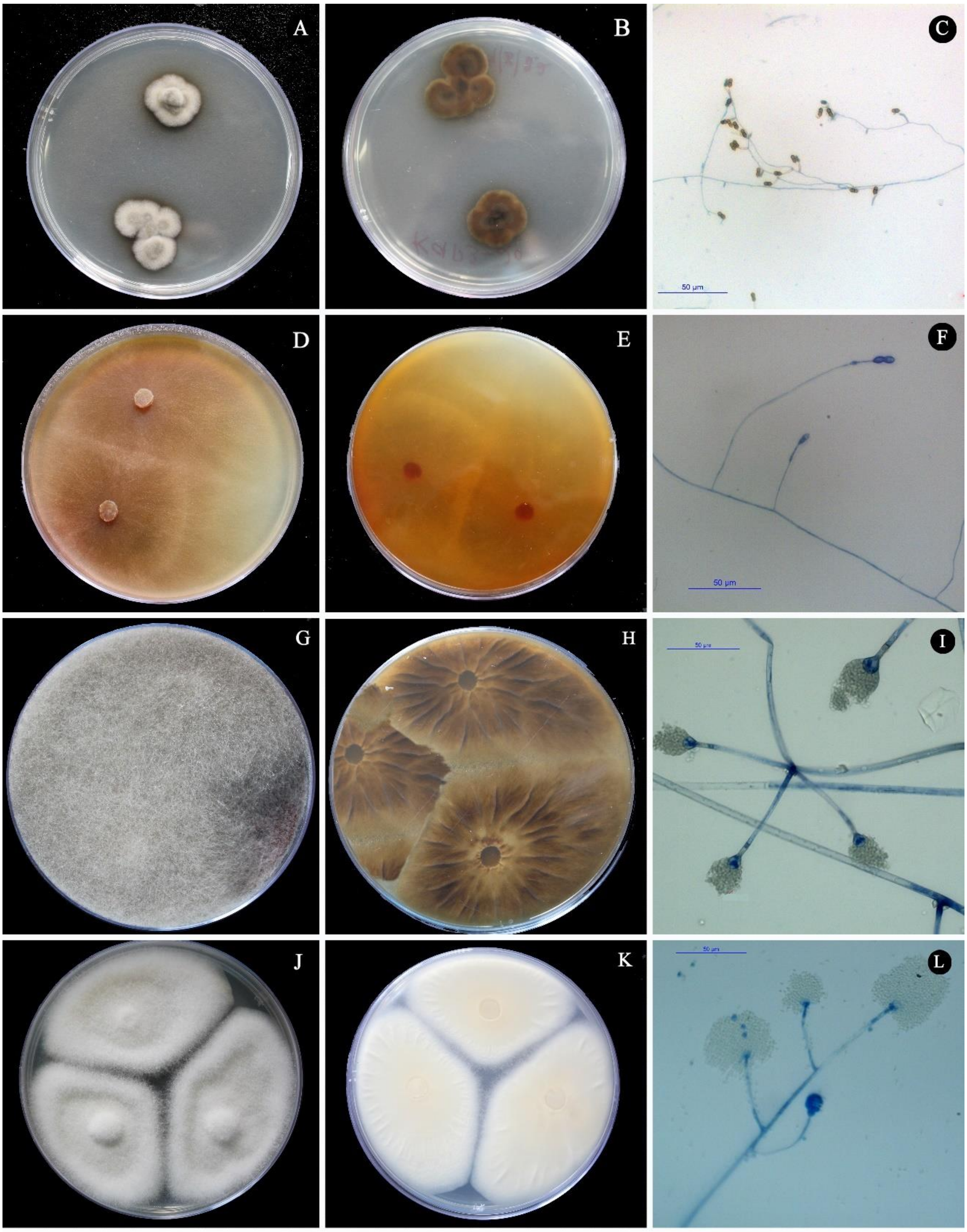

Plate 40. **A – C.** *Trichocladium* sp. 1. **D – F.** *Trichocladium* sp. 2. **G – I.** *Absidia cylindrospora*. **J – L.** *Gongronella butleri.* **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F.** Microscopic view with mycelium and aleurioconidia; **I.** Microscopic view with sporangiophore and sporangiospores; **L.** Microscopic view with sporangiophore, sporangia and sporangiospores.

Synonyms: *Cephalosporium roseogriseum* S.B. Saksena, Mycologia 47: 895 (1955), *Acremonium roseogriseum* (S.B. Saksena) W. Gams, *Cephalosporium artige* Schimmelpilze: 87 (1971).

Description: Colony floccose, in white to pinkish shade, reverse pink to brown shade; conidiophores as short branches of hyphae; conidia elliptical, in slimy heads, 5–7 x 2–3 µm.

Distribution: Isolated from Kollakal Thapovanam.

128. ***Gliomastix* sp. 1** **(Plate 32, J-L)**

Synonyms: Nil.

Description: Colony floccose, in white to yellow to grey colour, reverse cream to yellow shade; conidiophores simple; conidia elliptical, in chains, 5–6.3 x 2.7–2.8 µm.

Distribution: Isolated from Iringole Kavu.

Genus: *Sarocladium* W. Gams & D. Hawksw.

129. ***Sarocladium gamsii*** Giraldo, Gené, Guarro, in Giraldo et al., Phylogeny of *Sarocladium* (Hypocreales), pp. 15, Fig; 3 (2015). **(Plate 33, A-C)**

Synonyms: Nil.

Description: Colony velvety, in yellowish white colour, sulcations present, reverse yellow shade; conidiophores erect, simple or branched, smooth-walled, up to 48 µm long; phialides acicular; conidia fusiform, in chains and slimy heads, 2.6–3.2 x 0.9–1.4 µm.

Distribution: Isolated from Kollakal Thapovanam.

130. ***Sarocladium hominis*** Giraldo, Gené & D. A. Sutton, in Giraldo et al., Phylogeny of *Sarocladium* (Hypocreales), pp. 15, Fig; 4 (2015). **(Plate 33, D-F)**

Synonyms: Nil.

Description: Colony velvety, in yellowish white colour, concentric rings present, reverse bright yellow to orange shade; conidiophores erect, simple or branched, smooth-walled, 27–46 µm long; phialides acicular; conidia cylindrical with rounded ends, in slimy heads, 6.1–7.3 x 3.1–2.2 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

131. ***Sarocladium kiliense*** (Grütz) Summerb., in Domsch & Gams, Compendium of Soil Fungi, pp. 22, Fig. 9 (1980). **(Plate 33, G-I)**

Synonyms: *Acremonium kiliense* Grütz, Dermatol. Wochenschr.: 774 (1925), *Cephalosporium kiliense* (Grütz) E. Hartmann, Dermatol. Wochenschr.: 569 (1926), *Cephalosporium kiliense* (Grütz) E. Hartmann ex C.W. Dodge, Medical mycology. Fungous diseases of men and other mammals: 828 (1935), *Cephalosporium candidum* Sukapure & Thirum., Bulletin of the Torrey Botanical Club 93: 307 (1966), *Cephalosporium incarnatum* Sukapure & Thirum., Mycologia 55: 566 (1963), *Cephalosporium incarnatum* var. *macrosporum* Sukapure & Thirum., Mycologia 55: 568 (1963), *Cephalosporium infestans* Gaind & Thirum., Sabouraudia 1: 230 (1962), *Cephalosporium madurae* A.A. Padhye, Sukapure & Thirum., Mycopathologia et Mycologia Applicata 16: 318 (1962), *Papulaspora manganica* Beij., Folia Microbiologica Delft 2 (2): 1–12 (1913), *Cephalosporium niveolanosum* Benedek, Arch. Dermatol. Syph.: 166 (1928), *Hyalopus niveolanosus* (Benedek) M.A.J. Barbosa, Subsidios para o Estudo Parasitologico do Genero Hyalopus Corda, 1838: 46 (1941), *Cephalosporium stuehmeri* Schmidt & J.F.H. Beyma, Zentralblatt für Bakteriologie und Parasitenkunde Abteilung 1 130: 102 (1933), *Hyalopus stuehmeri* (Schmidt & J.F.H. Beyma) M.A.J. Barbosa, Subsidios para o Estudo Parasitologico do Genero Hyalopus Corda, 1838: 43 (1941), *Cephalosporium pseudofermentum* Cif., Arch. Protistenk.: 236 (1932), *Hyalopus pseudofermentum* (Cif.) M.A.J. Barbosa, Subsidios para o Estudo Parasitologico do Genero Hyalopus Corda, 1838: 17 (1941), *Cephalosporium asteroides-griseum-grutzmanii* Benedek (1928), *Cryptococcus pleomorpha* Gruner, Canadian Medical Association Journal 1: 15–19 (1935), *Cephalosporium asteroides-griseum-gruetzii* Benedek, Arch. Dermatol. Syph.: 166 (1928).

Description: Colony velvety, tufted, in white to pinkish colour, reverse dark brown to yellow shade, concentric rings present; phialides arising from submerged hyphae; conidia cylindrical, in slimy heads, 3.3–6.1 x 1.1–1.4 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

132. *Sarocladium* sp. 1 **(Plate 33, J-L)**

Synonyms: Nil.

Description: Colony velvety, yellow colour, reverse yellow shade; phialides from hyphae, aciculate, erect, up to 26 µm long; conidia ellipsoidal, in chains, 4.6–5.1 x 1.8–2.2 µm.

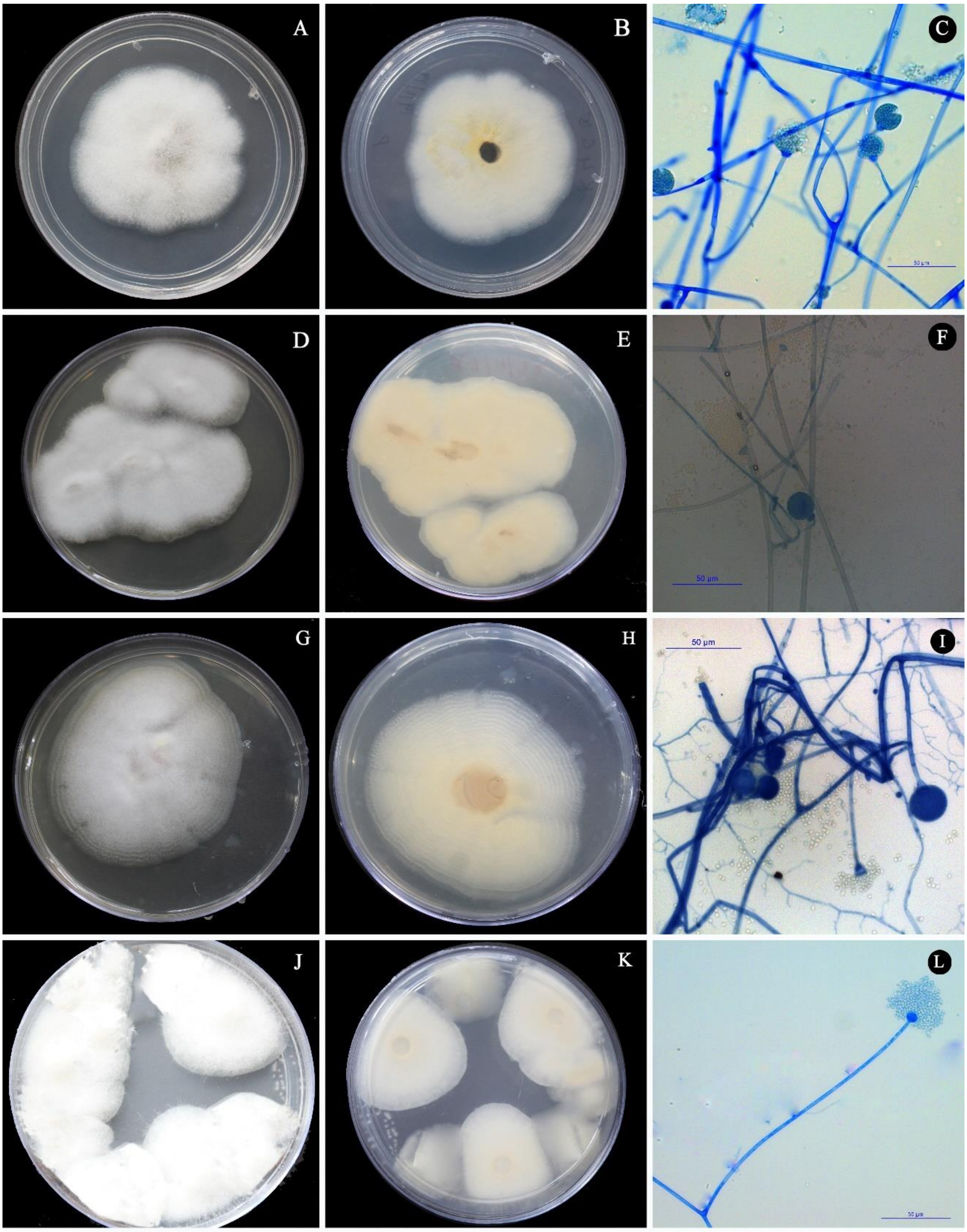

Plate 41. **A – C.** *Gongronella* sp. 1. **D – F.** *Gongronella* sp. 2. **G – I.** *Rhizomucor pusillus*. **J – L.** *Mucor bacilliformis*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F, I.** Microscopic view with sporangiophore, sporangia and sporangiospores; **L.** Microscopic view with sporangiophore and sporangiospores.

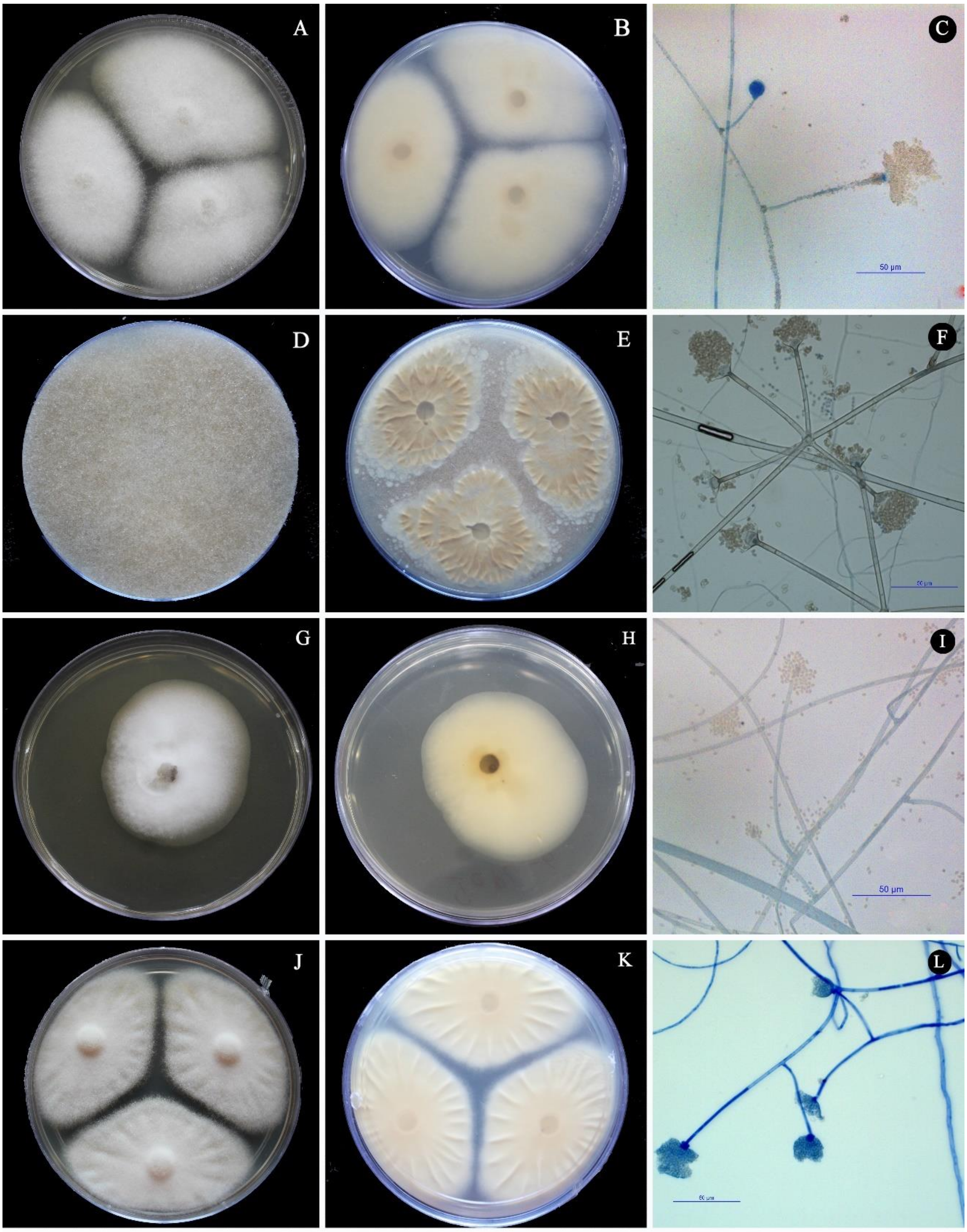

Plate 42. **A – C.** *Mucor circinelloides*. **D – F.** *Mucor hiemalis* f. *corticola*. **G – I.** *Mucor hiemalis* f. *hiemalis*. **J – L.** *Mucor mucedo*. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C.** Microscopic view with sporangiophore, sporangia and sporangiospores; **F, I, L.** Microscopic view with sporangiophore and sporangiospores.

Distribution: Isolated from Kollakal Thapovanam.

Family: Nectriaceae

Genus: *Cosmospora* Rabenh.

133. ***Cosmospora butyri*** (J.F.H. Beyma) Gräfenhan, Seifert & Schroers, in Domsch & Gams, Compendium of Soil Fungi, pp. 18, Fig. 5 (1980). **(Plate 34, A-C)**

Synonyms: *Tilachlidium butyri* J.F.H. Beyma, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 99: 388 (1939), *Acremonium butyri* (J.F.H. Beyma) W. Gams, Cephalosporium-artige Schimmelpilze: 126 (1971).

Description: Colony velvety to floccose, sulcations present, in olive green colour, reverse cream shade; conidiophores show verticillate ramifications; conidia in slimy heads, elongate-cylindrical, one-celled, 3.7–5 x 2.1–2.7 µm.

Distribution: Isolated from Iringole Kavu.

Genus: *Fusarium* Link

134. ***Fusarium oxysporum*** Schltdl., in Domsch & Gams, Compendium of Soil Fungi, pp. 323, Fig. 134 (1980). **(Plate 34, D-F)**

Synonyms: *Fusarium bulbigenum* Cooke & Massee, Grevillea 16 (78): 49 (1887), *Fusarium orthoceras* Appel & Wollenw., Arbeiten aus der Kaiserlichen Biologischen Anstalt für Land- und Forstwirtschaft 8: 155 (1910), *Fusarium vasinfectum* G.F. Atk., Bulletin of the Alabama Agricultural Experiment Station: 28 (1892), *Fusarium angustum* Sherb., Memoirs of the Cornell University Agricultural Experimental Station 6: 203 (1915), *Fusarium apii* R. Nelson & Sherb., Technical Bulletin of the Michigan Agriculture Experiment Station 155: 42 (1937), *Fusarium apii* var. *pallidum* R. Nelson & Sherb., Technical Bulletin of the Michigan Agriculture Experiment Station 155: 42 (1937), *Fusarium batatas* Wollenw., Journal of Agricultural Research 2: 268 (1914), *Fusarium cepae* Hanzawa, Mycol. Centralbl. 5 (1): 5 (1914), *Fusarium conglutinans* Wollenw., Berichte der Deutschen Botanischen Gesellschaft 31: 34 (1913), *Fusarium conglutinans* var. *betae* D. Stewart, Phytopathology 19: 59 (1931), *Fusarium conglutinans* var. *callistephi* Beach, Rep. Mich. Acad. Sci.: 281–308 (1918), *Fusarium conglutinans* var. *majus* Wollenw., Fusaria Autographice Delineata 3: 981 (1930), *Fusarium cubense* E.F. Sm., Science, N.S.: 754 (1910), *Fusarium dianthi* Prill. & Delacr., Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences 129: 745 (1899), *Fusarium lini* Bolley, Proceedings of the Annual Meeting of the Society for the Promotion of Agricultural Science 22: 42 (1901), *Fusarium lycopersici* Bruschi, Atti della Reale Accademia dei Lincei. Rendiconti di classe di Scienze Fisiche, Matematiche e Naturale 21: 298 (1912), *Fusarium perniciosum* Hepting, Circular, United States Department of Agriculture 535: 7 (1939), etc.

Description: Colony cottony, white, reverse cream to yellow shade; microconidia abundant, on short phialides, unicellular, ellipsoidal to cylindrical, 11–14 x 3.2–5 µm; macroconidia slightly curved, fusiform, 29–42 x 4.5–5.1 µm.

Distribution: Isolated from Iringole Kavu.

135. ***Fusarium tricinctum*** (Corda) Sacc., in Domsch & Gams, Compendium of Soil Fungi, pp. 339, Fig. 140 (1980). **(Plate 34, G-I)**

Synonyms: *Selenosporium tricinctum* Corda, Icones fungorum hucusque cognitorum 2: 7, tab. 9, fig. 33 (1838), *Fusarium sporotrichioides* var. *tricinctum* (Corda) Raillo, Fungi of the genus *Fusarium*: 197 (1950), *Fusarium tricinctum* var. *tricinctum* (Corda) Sacc., Sylloge Fungorum 4: 700 (1886), *Fusarium citriforme* Jamal., Valtion Maatalouskoetoiminnan Julkaisuja 123: 11 (1943), *Gibberella tricincta* El-Gholl, McRitchie, Schoult. & Ridings, Canad. J. Bot. 56 (18): 2206 (1978), *Fusarium muentzii* Delacr., Bull. Soc. Mycol. France 8: 192 (1892), *Vermicularia subeffigurata γ helianthi* Schwein., Transactions of the American Philosophical Society 4 (2): 228 (1832), *Vermicularia subeffigurata* var. *helianthi* (Schwein.) Sacc., Sylloge Fungorum 3: 231 (1884), *Fusarium helianthi* (Schwein.) Wollenw., Fusaria Autographice Delineata 2: 555 (1924).

Description: Colony velvety, in vinaceous to purple shade, reverse wine-red colour, microconidia abundant, unicellular, ellipsoidal, 4.5–9.2 x 2.3–5.2 µm; macroconidia rare.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

136. ***Fusarium verticillioides*** (Sacc.) Nirenberg, in Domsch & Gams, Compendium of Soil Fungi, pp. 319, Fig. 133 (1980). **(Plate 34, J-L)**

Synonyms: *Oospora verticillioides* Sacc., Fungi Italici Autographice Delineati. Fasc. 17–28: tab. 879 (1881), *Alysidium verticillioides* (Sacc.) Kuntze, Revisio generum plantarum 3 (3): 442 (1898), *Fusarium moniliforme* J. Sheld., Annual Report of the Nebraska Agricultural Experimental Station 17: 23 (1904), *Oospora*

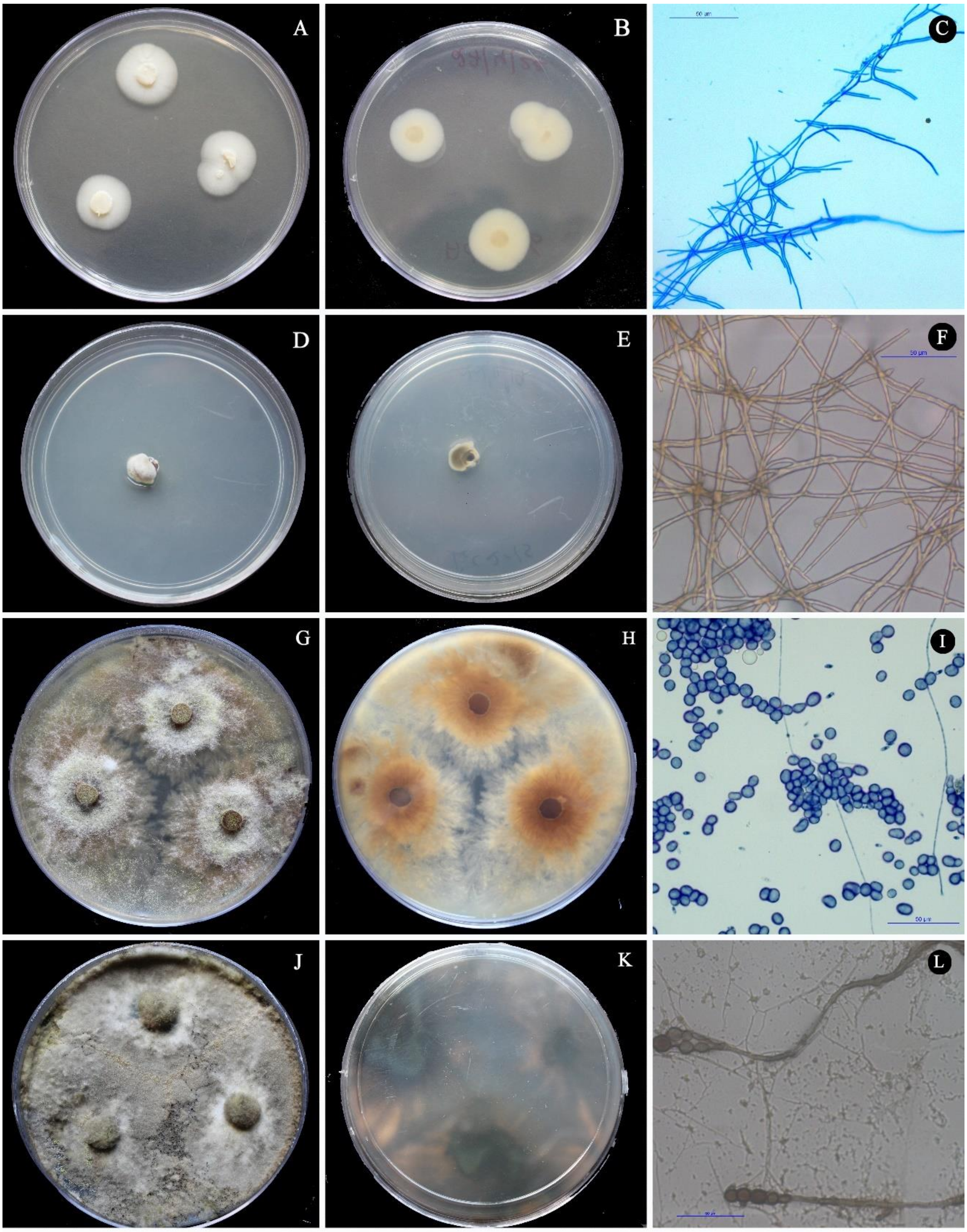

Plate 43. **A – C.** Non-sporulating fungi sp. 1. **D – F.** Non-sporulating fungi sp. 2. **G – I.** Unknown sp. 1. **J – L.** Unknown sp. 2. **A, D, G, J.** Colony obverse; **B, E, H, K.** Colony reverse; **C, F.** Microscopic view with mycelium; **I, L.** Microscopic view.

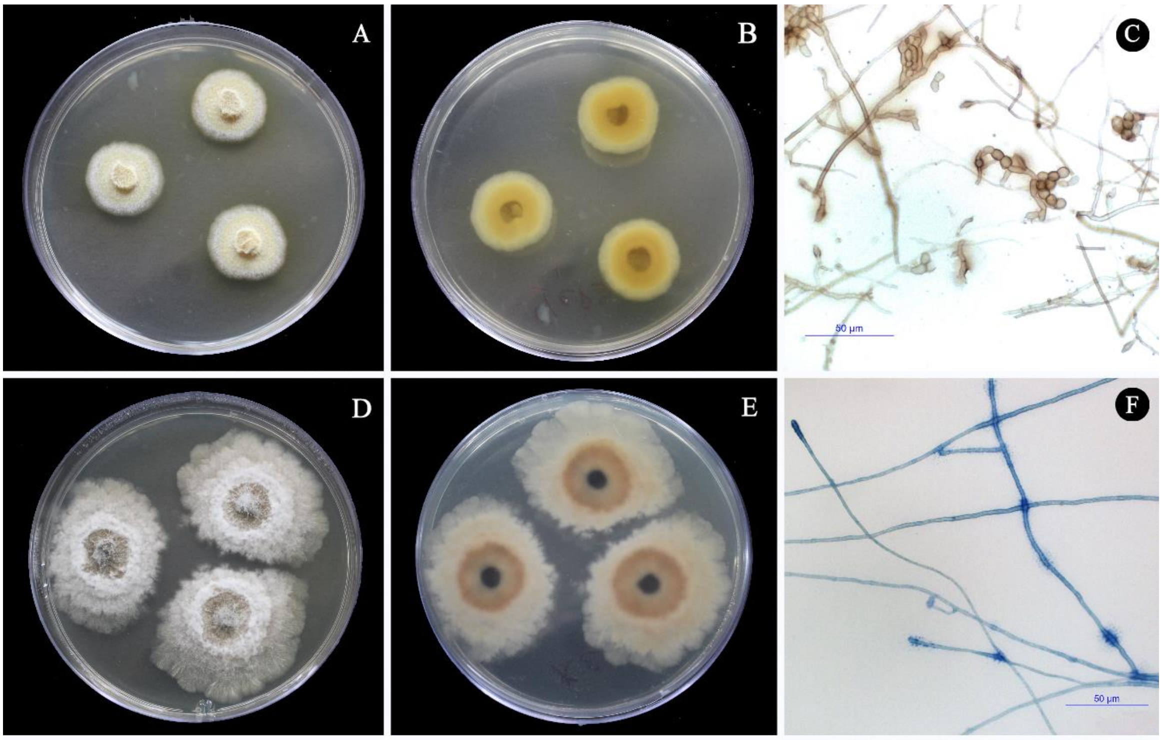

Plate 44. **A – C.** Unknown sp. 3. **D – F.** Unknown sp. 4. **A, D.** Colony obverse; **B, E.** Colony reverse; **C.** Microscopic view with conidiophore and conidia; **F.** Microscopic view with mycelium.

cephalosporioides Luchetti & Favilli, Annali della Facoltà di agraria della R. Università di Pisa 1: 399 (1938), *Gibberella moniliformis* Wineland, J. Agric. Res. 28: 909 (1924), *Gibberella fujikuroi* var. *moniliformis* (Wineland) Kuhlman, Mycologia 74: 765 (1982), *Fusarium samoense* Gehrm., Arbeiten Kaiserl. Biol. Anst. Land- Forstw. 9 (1): 24 (1913).

Description: Colony floccose, white, reverse white; microconidia abundant, clavate to cylindrical, 8.1–8.9 x 3.2–4.1 µm; macroconidia 3–5 septate, fusiform, slightly curved, pointed ends, 27–39 x 3.2–4.5 µm.

Distribution: Isolated from Poyilkavu.

137. *Fusarium* sp. 1 **(Plate 35, A-C)**

Synonyms: Nil.

Description: Colony velvety to floccose, in white to grey colour, reverse yellow-green shade; microconidia abundant, cylindrical, 2.4–3.5 x 1–1.3 µm; macroconidia rare.

Distribution: Isolated from Iringole Kavu and Kollakal Thapovanam.

138. *Fusarium* sp. 2 **(Plate 35, D-F)**

Synonyms: Nil.

Description: Colony velvety, tough, in cream colour, reverse cream shade; microconidia fusiform, pointed ends, non-septate, 3.2–4.6 x 1–1.6 µm; chlamydospores present, globose.

Distribution: Isolated from Poyilkavu.

Genus: *Mariannae* G. Arnaud ex Samson

139. *Mariannae* sp. 1 **(Plate 35, G-I)**

Synonyms: Nil.

Description: Colony velvety, colourless exudates present, purplish vinaceous shade, white margin, reverse cream to yellow shade; conidiophores simple, septate, 72–87 x 1.5–2 µm; phialides aculeate; conidia in imbricate conidial chains, elliptical, 1.8–2.2 x 2–2.1 µm.

Distribution: Isolated from Poyilkavu.

Genus: *Neocosmospora* E.F. Sm.

140. ***Neocosmospora solani*** (Mart.) L. Lombard & Crous, in Domsch & Gams, Compendium of Soil Fungi, pp. 333, Fig. 138 (1980). **(Plate 35, J-L)**

Synonyms: *Fusisporium solani* Mart., Die Kartoffel-Epidemie der letzten Jahre oder die Stockfäule und Räude der Kartoffeln: 20 (1842), *Fusarium solani* (Mart.) Sacc., Michelia 2 (7): 296 (1881), *Fusarium solani* (Mart.) Appel & Wollenw., Arbeiten aus der Kaiserlichen Biologischen Anstalt für Land- und Forstwirtschaft 8: 64–78 (1910), *Cephalosporium bertholletianum* J.A. Spencer, Botanical Gazette Crawfordsville 72: 279 (1921), *Fusarium eumartii* C.W. Carp., J. Agric. Res. 5: 204 (1915), *Fusarium solani* f. 2 W.C. Snyder, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 91: 174 (1934), *Nectria cancri* Rutgers, Ann. Jard. Bot. Buitenzorg, II: 59 (1913), *Hypomyces haematococcus* var. *cancri* (Rutgers) Wollenw., Fusaria Autographice Delineata 3: 829 (1930), *Fusarium striatum* Sherb., Memoirs of the Cornell University Agricultural Experimental Station 6: 255 (1915), *Fusisporium candidum* Bonord., Handbuch der allgemeinen Mykologie: 96 (1851), *Fusarium commutatum* Sacc., Syll. Fung. 4: 710 (1886), *Fusarium radicicola* Wollenw., Journal of Agricultural Research 2: 257 (1914), *Fusarium javanicum* var. *radicicola* (Wollenw.) Wollenw., Zeitschrift für Parasitenkunde 3: 286 (1931), *Fusarium solani* f. *radicicola* (Wollenw.) W.C. Snyder & H.N. Hansen, American Journal of Botany 28: 740 (1941), *Fusarium malli* Taubenh., Bulletin of the Texas Agricultural Experimental Station 273: 25 (1921), *Fusarium aduncisporum* Weimer & Harter, Journal of Agricultural Research 32: 312 (1926), *Fusarium solani* var. *aduncisporum* (Weimer & Harter) Wollenw., Fusaria Autographice Delineata 3: 1035 (1930), *Fusarium alluviale* Wollenw. & Reinking, Phytopathology 15 (3): 167 (1925), *Fusarium allii-sativi* Allesch., Ber. Bot. Vereines Landshut 12: 131 (1892), *Tubercularia subpedicellata* Schwein., Transactions of the American Philosophical Society 4 (2): 301 (1832), *Fusisporium solani-tuberosi* Desm., Ann. Sci. Nat., Bot. 3: 359 (1845), *Fusisporium rhizophilum* var. *solani-tuberosi* (Desm.) Westend., Bull. Acad. Roy. Sci. Belgique, Cl. Sci. 18 (2): 413 (1852), *Pionnotes viridis* Lechmere, Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences 155: 178 (1912), *Fusarium viride* (Lechmere) Wollenw., Fusaria Autographice Delineata 1: 418

(1916), *Neocosmospora rubicola* L. Lombard & Crous, Studies in Mycology 80: 227 (2015).

Description: Colony velvety to floccose, white to greenish grey shade, reverse grey shade; macroconidia 5-septate, moderately curved, short blunt apical cell, 47–56 µm long.

Distribution: Isolated from Iringole Kavu.

Family: Ophiocordycipitaceae

Genus: *Purpureocillium* Luangsa-ard, Hywel-Jones, Houbraken & Samson

141. ***Purpureocillium lilacinum*** (Thom) Luangsa-ard, Houbraken, Hywel-Jones & Samson, in Raper & Thom, A Manual of the Penicillia, pp. 285, Fig: 76,77 (1949). **(Plate 36, A-C)**

Synonyms: *Penicillium lilacinum* Thom, Bull. Bur. Anim. Ind. U.S. Dep. Agric.: 73 (1910), *Paecilomyces lilacinus* (Thom) Samson, Studies in Mycology 6: 58 (1974), *Spicaria rubidopurpurea* Aoki, Bull. Imp. Seri cult. Exp. Sta. Japan: 419–441 (1941).

Description: Colony floccose, loose texture, centre raised, colourless exudates present, white to vinaceous shade, reverse vinaceous to brown shade; conidiophores vary greatly, smooth-walled, 114–211 x 2–2.7 µm; penicilli divaricata; conidia elliptical, 2–3 x 2–2.3 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

142. ***Purpureocillium lilacinum*** (Thom) Luangsa-ard, Houbraken, Hywel-Jones & Samson **Natural Mutant**, in Raper & Thom, A Manual of the Penicillia, pp. 284 (1949). **(Plate 36, D-F)**

Synonyms: Nil.

Description: Colony velvety to floccose, radially furrowed, concentric rings present, colourless exudates present, white to yellow shade, reverse yellow shade; conidiophores short branches, smooth-walled, 11–13.5 x 2.4–3 µm; penicilli divaricata; conidia subglobose, 2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

Order: Microascales

Family: Microascaceae

Genus: *Cephalotrichum* Link

143. ***Cephalotrichum asperulum*** (J.E. Wright & S. Marchand) Sand.-Den., Guarro & Gené, in Sandoval-Denis et al., Phylogeny and taxonomic revision of Microascaceae with emphasis on synnematous fungi, pp. 201, Fig; 7 (2016).

(Plate 36, G-I)

Synonyms: *Doratomyces asperulus* J.E. Wright & S. Marchand, Boletín de la Sociedad Argentina de Botánica 14 (4): 308 (1972).

Description: Colony floccose, granular, in dark greenish colour, white margin, reverse yellow shade; conidiophores septate, smooth-walled, up to 1800 µm long; conidiogenous cells cylindrical, 10.9–11.7 x 3–4.6 µm; conidia elliptical, 5.7–6.3 x 3.1–3.8 µm.

Distribution: Isolated from Iringole Kavu.

Genus: *Microascus* Zukal

144. ***Microascus atrogriseus*** Woudenb. & Samson, in Woudenberg et al., *Scopulariopsis* and *scopulariopsis*-like species from indoor environments, pp. 14, Fig; 5 (2017). **(Plate 36, J-L)**

Synonyms: *Masonia grisea* G. Sm., Transactions of the British Mycological Society 35 (2): 149 (1952), *Masoniella grisea* (G. Sm.) G. Sm., Transactions of the British Mycological Society 35 (2): 237 (1952).

Description: Colony velvety, radially furrowed, colourless exudates present, in buff to coffee-brown colour, white colour margin, PDA changes to yellow, reverse yellow to bright orange shade; conidiophores simple, 1 or multiple annellides; annellides ampulliform, 9–11 x 2–3 µm, tapering to cylindrical annelated zone; conidia elliptical to clavate, arranged in chains, 3–4 x 2.2–3 µm.

Distribution: Isolated from Kollakal Thapovanam.

145. ***Microascus* sp. 1** **(Plate 37, A-C)**

Synonyms: Nil.

Description: Colony velvety, in white to baby pink colour, reverse dark brown to orange shade; conidiophores simple, multiple annellides present, terminate with an annellide; annellides ampulliform, 10–12.3 x 2–2.6 µm, tapering to cylindrical annelated zone; conidia globose, echinulate, arranged in chains, 3–3.5 µm in diameter.

Distribution: Isolated from Iringole Kavu.

Genus: *Scedosporium* Sacc. ex Castell. & Chalm.

146. ***Scedosporium apiospermum*** (Sacc.) Sacc. ex Castell. & Chalm., in Ramsperger et al., The Genus *Scedosporium* and *Pseudallescheria*: Current Challenges in Laboratory Diagnosis, pp. 29, 31 Fig; 1 (2014). **(Plate 37, D-F)**

Synonyms: *Monosporium apiospermum* Sacc., Annales Mycologici 9 (3): 254 (1911), *Aleurisma apiospermum* (Sacc.) Maire, Bull. Soc. Pathol. Exot.: 290 (1921), *Indiella americana* Delamare & Gatti, Compt. Rend. Hebd. Séances Acad. Sci., Sér. D: 1264 (1929), *Madurella americana* (Delamare & Gatti) Vuill., Encyclopédie Mycologique 2: 155 (1931), *Acremonium suis* Bakai, Bolezni Svinei, Kiev: 198 (1967), *Polycytella hominis* C.K. Campb., Journal of Medical and Veterinary Mycology 25 (5): 302 (1987), *Dendrostilbella boydii* Shear, Mycologia 14 (5): 242 (1922), *Glenospora clapieri* Catanei, Bull. Soc. Pathol. Exot.: 502 (1927), *Trichosporum clapieri* (Catanei) C.W. Dodge, Medical mycology. Fungous diseases of men and other mammals: 794 (1935), *Madurella clapieri* (Catanei) Redaelli & Cif., Mycopathologia 3: 196 (1941), *Monosporium sclerotiale* Pepere, Soc. Cult. Sci. Med. Nat. Cagl.: 543 (1914), *Scedosporium sclerotiale* (Pepere) Castell. & Chalm., Manual of Tropical Medicine: 1123 (1919), *Monosporium apiospermum* var. *peperei* Sartory, Champ. Paras. Homme Anim.: 681 (1922), *Streptothrix tarozzii* Miescher, Arch. Dermatol. Syph.: 297–442 (1917), *Pseudallescheria apiosperma* Gilgado, Gené, Cano & Guarro, Med. Mycol. 48 (1): 127 (2010).

Description: Colony floccose, in greyish white to black colour, reverse brown to black shade; conidiophores branched or simple; conidia clavate to ovoid, brown, borne singly or in groups, 9–12 x 4.8–8.9 µm.

Distribution: Isolated from Iringole Kavu.

147. ***Scedosporium* sp. 1** **(Plate 37, G-I)**

Synonyms: Nil.

Description: Colony velvety, in white colour, reverse yellow to orange shade; conidiophores branched or simple, short; conidia clavate, borne singly, 4.8–5 x 3.6–4.2 µm.

Distribution: Isolated from Iringole Kavu.

Genus: *Scopulariopsis* Bainier

148. ***Scopulariopsis asperula*** (Sacc.) S. Hughes, in Domsch & Gams, Compendium of Soil Fungi, pp. 731, Fig. 324 (1980). **(Plate 37, J-L)**

Synonyms: *Torula asperula* Sacc., Michelia 2 (8): 560 (1882), *Acaulium nigrum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 47 (1912), *Microascus niger* (Sopp) Curzi, Bolletino della Stazione di Patologia Vegetale di Roma 11: 8 (1931), *Penicillium nigrum* (Sopp) Biourge, La Cellule 33: 1043 (1923), *Scopulariopsis fusca* Zach, Österreichische Botanische Zeitschrift 83 (3): 174 (1934), *Torula bestae* Pollacci, Riv. Biol.: 317 (1922), *Scopulariopsis bestae* (Pollacci) Nann., Repertorio sistematico dei miceti dell' uomo e degli animali 4: 254 (1934), *Scopulariopsis ivorensis* H. Boucher, Bulletin de la Société de Pathologie Exotique 11: 313 (1918), *Scopulariopsis roseola* N. Inagaki, Transactions of the Mycological Society of Japan 4: 1 (1962), *Scopulariopsis repens* Bainier, Bulletin de la Société Mycologique de France 23: 125 (1907), *Penicillium repens* (Bainier) Biourge, La Cellule 33: 225 (1923), *Monilia arnoldii* L. Mangin & Pat., Bull. Soc. Mycol. France: 164 (1908), *Scopulariopsis arnoldii* (L. Mangin & Pat.) Vuill., Bulletin de la Société Mycologique de France 27: 148 (1911), *Acaulium nigrum* var. *glabrum* Salv.-Duval (1935).

Description: Colony velvety, in fuscous grey colour, reverse yellow shade; annellophores arising singly on in groups; conidiogenous cells cylindrical with swollen base; conidia globose to ovate, 2.7–6.2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

149. ***Scopulariopsis brevicaulis*** (Sacc.) Bainier, in Domsch & Gams, Compendium of Soil Fungi, pp. 726, Fig. 321 (1980). **(Plate 38, A-C)**

Synonyms: *Penicillium brevicaule* Sacc., Michelia 2 (8): 547 (1882), *Acaulium insectivorum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 60 (1912), *Penicillium insectivorum* (Sopp) Biourge, La Cellule 33: 103 (1923), *Scopulariopsis insectivora* (Sopp) Thom, The Penicillia: 532 (1930), *Monilia koningii* Oudem., Archives Néerlandaises 7: 287 (1902), *Scopulariopsis koningii* (Oudem.) Vuill., Bulletin de la Société Mycologique de France 27: 143 (1911), *Sporotrichum stercorarium* Link, Jahrbücher der Gewächskunde 1 (1): 178 (1818), *Scopulariopsis stercoraria*

(Link) S. Hughes, Canadian Journal of Botany 36 (6): 803 (1958), *Microascus brevicaulis* S.P. Abbott, Mycologia 90: 298 (1998), *Scopulariopsis rufulus* Bainier, Bulletin de la Société Mycologique de France 23: 105 (1907), *Penicillium rufulum* (Bainier) Sacc., Sylloge Fungorum 22: 1275 (1913), *Monilia penicillioides* Delacr., Bulletin de la Société Mycologique de France 13: 114 (1897), *Penicillium penicillioides* (Delacr.) Vuill., Bulletin de la Société Mycologique de France 27: 75 (1911), *Acaulium anomalum* Sopp, Skrifter udgivne af Videnskabs-Selskabet i Christiania. Mathematisk-Naturvidenskabelig Klasse 11: 65 (1912), *Penicillium brevicaule* var. *hominis* Brumpt & Langeron, Précis de parasitologie: 838 (1910), *Scopulariopsis brevicaulis* var. *hominis* (Brumpt & Langeron) Brumpt & Langeron, Précis de parasitologie: 902 (1913), *Scopulariopsis hominis* (Brumpt & Langeron) Sartory, Champ. Paras.: 612 (1922), *Penicillium coccophilum* Sacc., Annales Mycologici 5 (2): 178 (1907).

Description: Colony velvety to funiculose, in white to vinaceous buff colour, reverse honey coloured; conidiophores once or twice branched; 2–4 annellophores; conidiogenous cells with swollen base; conidia globose to ovate, finely roughened, verrucose, 4.4–5.2 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

150. ***Scopulariopsis candida*** Vuill., in Domsch & Gams, Compendium of Soil Fungi, pp. 725 (1980). **(Plate 38, D-F)**

Synonyms: *Monilia candida Guég.: 271 (1899).*

Description: Colony velvety to funiculose, in white to light vinaceous buff colour, colourless exudates present, reverse yellow to orange; conidiophores unbranched; 2–4 annellophores; conidia smooth-walled, globose to subglobose, 2.9–3.3 µm in diameter.

Distribution: Isolated from Poyilkavu.

151. ***Scopulariopsis* sp. 1** **(Plate 38, G-I)**

Synonyms: Nil.

Description: Colony cottony, in white colour, reverse yellow shade; conidiophores unbranched; single annellophores; conidia globose to subglobose, smooth-walled, 1.9–2.2 µm in diameter.

Distribution: Isolated from Iringole Kavu.

Genus: *Wardomyces* F.T. Brooks & Hansf.

152. ***Wardomyces inflatus*** (Marchal) Hennebert, in Sandoval-Denis et al., Phylogeny and taxonomic revision of Microascaceae with emphasis on synnematous fungi, pp. 221, Fig. 26 (2016). **(Plate 38, J-L)**

Synonyms: *Trichosporum inflatum* Marchal, Bull. Soc. Roy. Bot. Belgique 34: 142 (1895), *Wardomyces hughesii* Hennebert, Canadian Journal of Botany 40 (9): 1207 (1962).

Description: Colony velvety, brown to black colour, reverse cream shade; conidiophores unbranched; conidia dark brown, 2-celled, smooth, ellipsoidal to cylindrical, 4.6–7 x 2.5–3.8 µm.

Distribution: Isolated from Poyilkavu.

Order: Chaetosphaeriales

Family: Chaetosphaeriaceae

Genus: *Chloridium* Link

153. ***Chloridium guttiferum*** Réblová & Hern.-Restr., in Réblová et al., Consolidation of *Chloridium*: new classification into eight sections with 37 species and reinstatement of the genera *Gongromeriza* and *Psilobotrys*, pp. 146, Fig. 29 (2022). **(Plate 39, A-C)**

Synonyms: Nil.

Description: Colony floccose, in olivaceous grey colour, PDA changes to brown, reverse cream to brown shade; conidiophores erect, septate, simple, short, gradually tapering towards apex with terminal phialide, smooth-walled, 23–56 x 2.5–3.9 µm; conidia ellipsoidal, 3.3–3.9 x 2.6–2.8 µm.

Distribution: Isolated from Poyilkavu.

154. ***Chloridium* sp. 1** **(Plate 39, D-F)**

Synonyms: Nil.

Description: Colony velvety, in olivaceous grey to black colour, reverse red to brown shade; conidiophores brown colour, erect, septate, whorls of phialides at regular distance, gradually tapering towards apex with terminal phialide, smooth-walled, 132–150 x 4.5–5.2 µm; conidia ellipsoidal, 2–2.6 x 1.8–2 µm.

Distribution: Isolated from Kollakal Thapovanam.

155. ***Chloridium* sp. 2** **(Plate 39, G-I)**

Synonyms: Nil.

Description: Colony floccose, in olivaceous-to-olivaceous grey colour, reverse cream to brown shade; conidiophores brown colour, erect, septate, branched, gradually tapering towards apex with terminal phialide, smooth-walled, 32–56 x 4–4.8 µm; conidia ellipsoidal, 4–6.3 x 2.7–3 µm.

Distribution: Isolated from Iringole Kavu.

Order: Diaporthales

Family: Insertae sedis

Genus: *Sirococcus* Preuss

156. ***Sirococcus tsugae*** Rossman, Castl., D.F. Farr & Stanosz, in Rossman et al., *Sirococcus conigenus, Sirococcus piceicola* sp. nov. and *Sirococcus tsugae* sp. nov. on conifers: anamorphic fungi in the Gnomoniaceae, Diaporthales, pp. 53, Fig. 7–10 (2008). **(Plate 39, J-L)**

Synonyms: Nil.

Description: Colony velvety to floccose, in yellowish green shade, white colour margin, reverse cream to yellow shade; conidiophores branched, septate; conidia fusiform, 7–9 x 2.6–3.1 µm.

Distribution: Isolated from Iringole Kavu.

Order: Sordariales

Family: Chaetomiaceae

Genus: *Trichocladium* Harz

157. ***Trichocladium* sp. 1** **(Plate 40, A-C)**

Synonyms: Nil.

Description: Colony velvety, in white to brown to black colour, PDA turns to black, reverse brown black shade; aleurioconidia on short stalks, 2-celled, clavate, smooth-walled, 6.4–6.7 x 2.6–2.9 µm.

Distribution: Isolated from Kollakal Thapovanam.

158. ***Trichocladium* sp. 2** **(Plate 40, D-F)**

Synonyms: Nil.

Description: Colony velvety, yellow to red shade, PDA turns to red, reverse red shade; aleurioconidia on long stalks, 2–3 celled, clavate, smooth-walled, 13.9–14.3 x 4.7–8.1 µm.

Distribution: Isolated from Poyilkavu.

Phylum: Mucoromycota
Class: Mucoromycetes
Order: Mucorales
Family: Cunninghamellaceae
Genus: *Absidia* Tiegh.

159. ***Absidia cylindrospora*** Hagem, in Domsch & Gams, Compendium of Soil Fungi, pp. 10, Fig. 2 (1980). **(Plate 40, G-I)**

Synonyms: *Mycocladus altaini* S.A. Kulik, Notul. syst. Inst. cryptog. Horti bot. petropol.: 134 (1960).

Description: Colony floccose, in brown colour, reverse brown shade, striations present; sporangiophores arising in whorls, unbranched; spores cylindrical 3–3.1 µm in diameter.

Distribution: Isolated from Iringole Kavu.

Genus: *Gongronella* Ribaldi

160. ***Gongronella butleri*** (Lendn.) Peyronel & Dal Vesco, in Domsch & Gams, Compendium of Soil Fungi, pp. 381, Fig. 156 (1980). **(Plate 40, J-L)**

Synonyms: *Absidia butleri* Lendn., Bulletin de la Société Botanique de Genève 18 (2): 181 (1926), *Tieghemella butleri* (Lendn.) Naumov, Opredelitel Mukorovykh (Mucorales): 82 (1935), *Mortierella butleri* (Lendn.) Chalab., Novosti Sistematiki Nizshikh Rastenii 4: 164 (1967), *Gongronella urceolifera* Ribaldi, Rivista di Biologia 49 (1): 164 (1952), *Absidia subpoculata* F.S. Paine, Mycologia 19: 251 (1927), *Tieghemella subpoculata* (F.S. Paine) Naumov, Opredelitel Mukorovykh (Mucorales): 82 (1935), *Mucor vesiculosus* G. Sm., Transactions of the British Mycological Society 40: 481 (1957), *Mortierella vesiculosa* (G. Sm.) Chalab., Novosti Sistematiki Nizshikh Rastenii 4: 163 (1967), *Acremonium ossicola* Cif. & Redaelli, Atti dell'Istituto Botanico della Università e Laboratorio Crittogamico di Pavia 3 (1): 12 (1943).

Description: Colony floccose, in cream to white colour, reverse cream shade, striations present; sporangiophores erect, branched; sporangia globose, reduced columella; spores oval, 2–4.1 x 1.4–2.2 µm.

Distribution: Isolated from Iringole Kavu and Poyilkavu.

161. *Gongronella* sp. 1 **(Plate 41, A-C)**

Synonyms: Nil.

Description: Colony velvety to puffy, in white colour, colourless exudates present, reverse cream to yellow shade, wet-like; sporangiophores erect, branched, short; sporangia globose, 18–20 µm in diameter, reduced columella; spores elliptical, 2.5–2.7 x 1.3–1.5 µm.

Distribution: Isolated from Poyilkavu.

162. *Gongronella* sp. 2 **(Plate 41, D-F)**

Synonyms: Nil.

Description: Colony velvety, tough, in white colour, transparent margin, reverse cream to yellow shade; sporangiophores erect, short; sporangia globose, 20–23 µm in diameter, reduced columella; spores cylindrical, 2.9–3.1 x 1.4–1.9 µm.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

Family: Lichtheimiaceae

Genus: *Rhizomucor* Lucet & Costantin

163. *Rhizomucor pusillus* (Lindt) Schipper, in Domsch & Gams, Compendium of Soil Fungi, pp. 700, Fig. 310 (1980). **(Plate 41, G-I)**

Synonyms: *Mucor pusillus* Lindt, Arch. Exp. Path. Pharmacol.: 272 (1886), *Mucor buntingii* Lendn., Bulletin de la Société Botanique de Genève 21: 260 (1930), *Mucor tauricus* Milko & Schkur., Novosti Sistematiki Nizshikh Rastenii 7: 139 (1970), *Rhizomucor tauricus* (Milko & Schkur.) Schipper, Studies in Mycology 17: 62 (1978), *Rhizomucor pusillus* var. *tauricus* (Milko & Schkur.) R.Y. Zheng, X.Y. Liu & R.Y. Li, Sydowia 61 (1): 144 (2009), *Mucor septatus* Bezold, Die Schimmelmykosen des menschlichen Ohres: 97 (1889), *Rhizomucor septatus* (Bezold) Lucet & Costantin, Archs Parasit.: 362 (1901), *Mucor parasiticus* Lucet & Costantin, Compt. Rend. Hebd. Séances Acad. Sci., Sér. D: 1033 (1899), *Rhizomucor parasiticus* (Lucet & Costantin) Lucet & Costantin, Rev. Gén. Bot.: 81 (1900), *Rhizopus parasiticus* (Lucet & Costantin) Lendn., Matériaux pour la Flore Cryptogamique Suisse 3 (1): 115 (1908), *Rhizomucor pusillus* var. *pusillus* (Lindt) Schipper (1978).

Description: Colony floccose, in white colour, reverse cream yellow shade; sporangiophores with sympodial branching, 3–4 µm wide, rhizoids present at the base; sporangia with subglobose to elongate columellae; sporangiospores subglobose, 2–25 µm in diameter.

Distribution: Isolated from Poyilkavu.

Family: Mucoraceae

Genus: *Mucor* P. Micheli ex L.

164. ***Mucor bacilliformis*** Hesselt., in Hesseltine, The Section Genevensis of the Genus *Mucor*, pp. 360, Fig. 1 (1954). **(Plate 41, J-L)**

Synonyms: *Zygorhynchus bacilliformis* (Hesselt.) Arx, Sydowia 35: 16 (1982).

Description: Colony floccose, in white colour, reverse cream yellow shade; sporangiophores unbranched, smooth-walled, 3–6 µm in diameter; sporangia wall smooth, columellae globose; sporangiospores elliptical, 2.6–4.2 x 1.8–2.1 µm.

Distribution: Isolated from Poyilkavu.

165. ***Mucor circinelloides*** Tiegh., in Hesseltine., in Domsch & Gams, Compendium of Soil Fungi, pp. 463, Fig. 196 (1980). **(Plate 42, A-C)**

Synonyms: *Circinomucor circinelloides* (Tiegh.) Arx, Sydowia 35: 18 (1982), *Calyptromyces circinelloides* (Tiegh.) Sumst., Mycologia 2: 148 (1910), *Mucor circinelloides* f. *circinelloides* Tiegh., Annales des Sciences Naturelles Botanique sér. 6, 1: 94 (1875), *Mucor dubius* Wehmer, ZentBl. Bakt. ParasitKde, Abt. 2: 318 (1901), *Mucor javanicus* Wehmer, ZentBl. Bakt. ParasitKde, Abt. 2: 619 (1900), *Mucor mandshuricus* Saito, Mikrobiologische Studien über die Bereitung des mandschurischen Branntweins: 16 (1914), *Mucor prainii* Chodat & Nechitsche, Inst. Bot. Univ. Genève: 38 (1904), *Mucor ramificus* B.S. Mehrotra & Nand, Sydowia 20 (1–6): 69 (1966), *Rhizomucor variabilis* var. *regularior* R.Y. Zheng & G.Q. Chen, Mycosystema 6: 2 (1993), *Rhizomucor regularior* (R.Y. Zheng & G.Q. Chen) R.Y. Zheng, X.Y. Liu & R.Y. Li, Sydowia 61 (1): 144 (2009), *Mucor alternans* Tiegh., Annls Inst. Pasteur, Paris: 532 (1876), *Mucor ambiguus* Vuill., Bull. Séanc. Soc. Sci. Nancy: 92 (1887), *Mucor circinelloides* var. *circinelloides* Tiegh., Annales des Sciences Naturelles Botanique sér. 6, 1: 94 (1875).

Description: Colonies cottony, white to brown, reverse cream to yellow shade; sporangiophores mostly branched sympodially, 33–189 × 3–5 µm; sporangia terminal, columellae hyaline globose or subglobose; sporangiospores ellipsoidal to subglobose 4–4.8 × 3.2–4.6 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

166. ***Mucor hiemalis*** **f.** ***corticola*** (Hagem) Schipper, in Domsch & Gams, Compendium of Soil Fungi, pp. 470, Fig. 197 (1980). **(Plate 42, D-F)**

Synonyms: *Mucor corticola* Hagem, Annales Mycologici 8 (3): 265 (1910), *Mucor corticolus* Hagem (1910).

Description: Colony floccose, in rosy buff to brown colour, reverse brown colour; sporangiophores sympodially branched, 4–10 µm wide; sporangia with ellipsoidal columellae; sporangiospore cylindrical-ellipsoidal, 4–5 x 2–3 µm.

Distribution: Isolated from Kollakal Thapovanam and Poyilkavu.

167. ***Mucor hiemalis*** Wehmer **f.** ***hiemalis***., in Domsch & Gams, Compendium of Soil Fungi, pp. 466, Fig. 197 (1980). **(Plate 42, G-I)**

Synonyms: *Mucor adventitius* Oudem., Nederlandsch Kruidkundig Archief 2 (3): 719 (1902), *Mucor humicolus* Raillo (1929), *Mucor lausannensis* Lendn., Matériaux pour la Flore Cryptogamique Suisse 3 (1): 75 (1908), *Mucor vallesiacus* Lendn., Bulletin de la Société Botanique de Genève sér. 2, 10: 362 (1918), *Mucor adventitius* var. *aurantiacus* Lendn., Matériaux pour la Flore Cryptogamique Suisse 3 (1): 64 (1908), *Mucor hiemalis* var. *albus* Lendn., Bull. Soc. bot. Genève: 365 (1918), *Mucor hiemalis* var. *flavus* Zycha, Kryptogamen-Flora der Mark Brandenburg 6a: 75 (1935), *Mucor hiemalis* var. *griseus* Zycha, Kryptogamen-Flora der Mark Brandenburg 6a: 75 (1935), *Mucor hiemalis* var. *toundrae* Lendn., Bull. Soc. bot. Genève: 373 (1918), *Mucor humicola* Raillo, Zentralblatt für Bakteriologie und Parasitenkunde, Abteilung 2 78: 515 (1929).

Description: Colony velvety, in white to buff colour, reverse luteous; sporangiophores sympodially branched, 4–10 µm wide; sporangia with globose columellae; sporangiospore ellipsoidal, 3–6.2 x 2.1–3.2 µm.

Distribution: Isolated from Iringole Kavu, Kollakal Thapovanam and Poyilkavu.

168. ***Mucor mucedo*** (Mich) L., in Domsch & Gams, Compendium of Soil Fungi, pp. 472, Fig. 199 (1980). **(Plate 42, J-L)**

Synonyms: *Ascophora vulgaris* Gray, A natural arrangement of British plants 1: 561 (1821), *Mucor coprophilus* Povah, Bulletin of the Torrey Botanical Club 44: 297 (1917), *Mucor griseo-ochraceus* Naumov, Mater. Mykol. Fitopatol. Rossia: 9 (1915), *Mucor murorum* Naumov, Mater. Mykol. Fitopatol. Rossia: 11 (1915), *Hydrophora stercorea* Tode, Fungi Mecklenburgenses Selecti 2: 6 (1791), *Mucor stercoreus* (Tode) Link, Caroli a Linné Species Plantarum exhibentes Plantas Rite Cognitas ad Genera Relatas 6 (1): 90 (1824), *Ascophora stercorea* (Tode) Corda, Icones fungorum hucusque cognitorum 6: 11, t. 2:31 (1854), *Mucor caninus* Pers., Observationes mycologicae 1: 96, t. 6:3–4 (1796), *Mucor mucedo* subsp. *caninus* (Pers.) Sacc., Sylloge Fungorum 7: 191 (1888), *Mucor griseoochraceus* Naumov (1915).

Description: Colony floccose, in white to yellow colour, sulcations present, reverse cream to white colour; sporangiophores simple, branched, 55–82 µm in length; sporangia with persistent walls; sporangiospores thick-walled elliptical, cylindrical-ellipsoidal, 6–7 µm in diameter.

Distribution: Isolated from Kollakal Thapovanam.

Non-sporulating Fungi

169. Non-sporulating Fungi 1 (Plate 43, A-C)

Synonyms: Nil.

Colony velvety, cream colour, reverse cream colour; no spores or conidia; only mycelium present.

Distribution: Isolated from Kollakal Thapovanam.

170. Non-sporulating Fungi 2 (Plate 43, D-F)

Synonyms: Nil.

Colony brownish-black colour, reverse brown colour; no spores or conidia; only mycelium present.

Distribution: Isolated from Iringole Kavu.

Unknown Species

171. Unknown sp. 1 (Plate 43, G-I)

Synonyms: Nil

Description: Colony cottony, yellowish-cream colour, reverse orange-brown shade; spore-like structures present.

Distribution: Isolated from Iringole Kavu.

172. Unknown sp. 2 **(Plate 43, J-L)**

Synonyms: Nil

Description: Colony floccose, brownish-black colour, reverse dark black colour; only chlamydospores present.

Distribution: Isolated from Iringole Kavu.

173. Unknown sp. 3 **(Plate 44, A-C)**

Synonyms: Nil.

Description: Colony velvety, middle yellow colour, with white colour margin, reverse orange-yellow shade; PDA turns to yellow colour; spores present in chains.

Distribution: Isolated from Iringole Kavu.

174. Unknown sp. 4 **(Plate 44, D – E)**

Synonyms: Nil.

Description: Colony floccose, middle brown colour, then white colour, reverse dark brown shade in middle; mycelia with some swellings present.

Distribution: Isolated from Poyilkavu.

4.1.2 New Reports from the study

From the study, 16 new reports to India and 18 new reports to Kerala were recorded and was listed below.

4.1.2.1 New report to India

1. *Aspergillus caesiellus*
2. *Aspergillus coremiiformis*
3. *Aspergillus duricaulis*
4. *Aspergillus koningii*
5. *Aspergillus raperi*
6. *Aspergillus subalbidus*
7. *Paecilomyces stipitatus*
8. *Penicillium crystallinum*
9. *Penicillium paxilli*
10. *Talaromyces brunneus*
11. *Talaromyces piceae*
12. *Sarocladium gamsii*
13. *Sarocladium hominis*
14. *Chloridium guttiferum*
15. *Sirococcus tsugae*
16. *Mucor bacilliformis*

4.1.2.2 New report to Kerala

1. *Aspergillus flavus* var. *columnaris*
2. *Aspergillus petrakii*
3. *Paecilomyces victoriae*
4. *Penicillium adametzii*
5. *Penicillium capsulatum*
6. *Penicillium granulatum*
7. *Talaromyces duclauxii*
8. *Talaromyces flavus*
9. *Trichoderma spirale*
10. *Gliomastix roseogrisea*
11. *Mucor hiemalis* f. *corticola*
12. *Penicillium cyaneum*
13. *Talaromyces atroroseus*
14. *Furcasterigmium furcatum*
15. *Plectosphaerella cucumerina*
16. *Microascus atrogriseus*
17. *Scopulariopsis asperula*
18. *Scopulariopsis candida*

4.2 Quantitative Analysis

Ascomycota becomes the most dominant phyla, contributing 158 species out of the 168 identified species. These species belong to 34 genera, 16 families, 11 orders, 7 subclasses, and 5 classes. In contrast, Mucoromycota contributes only 10 species, which belong to 4 genera, 3 families, 1 order, 1 subclass, and 1 class.

Class-wise contribution of fungi from the study area is represented as a pie chart (Figure 3). Eurotiomycetes exhibit the highest abundance (47%), followed by Sordariomycetes (37%). Saccharomycetes and Leotiomycetes have the lowest abundance (0.05%).

Table 6 gives the site-wise and season-wise distribution of taxa during the study period and Figure 4 depicts the spatial distribution of taxonomic rank. Iringole Kavu has the highest number of species (105), followed by Poyilkavu (67) and Kollakal Thapovanam (64).

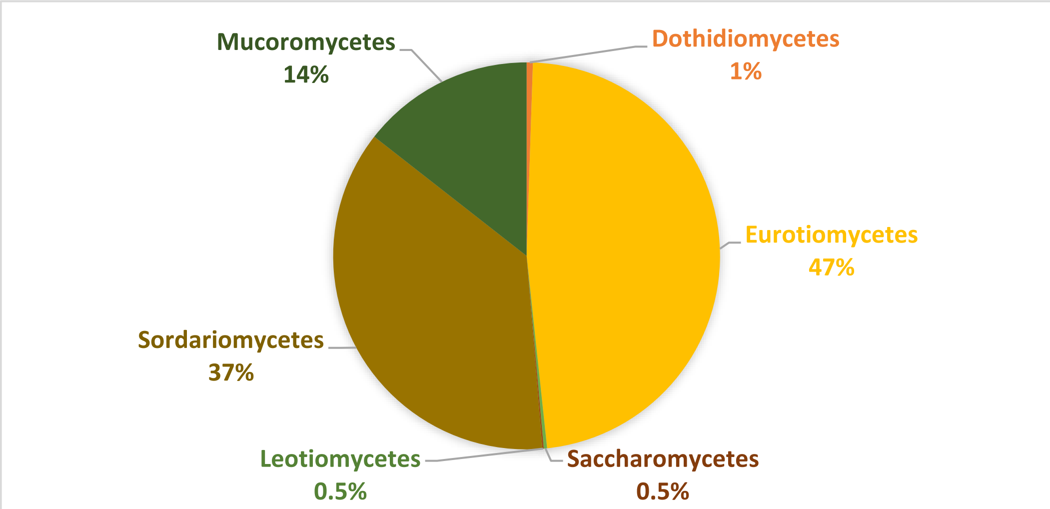

Figure 3. Pie chart showing the class-wise analysis of fungi

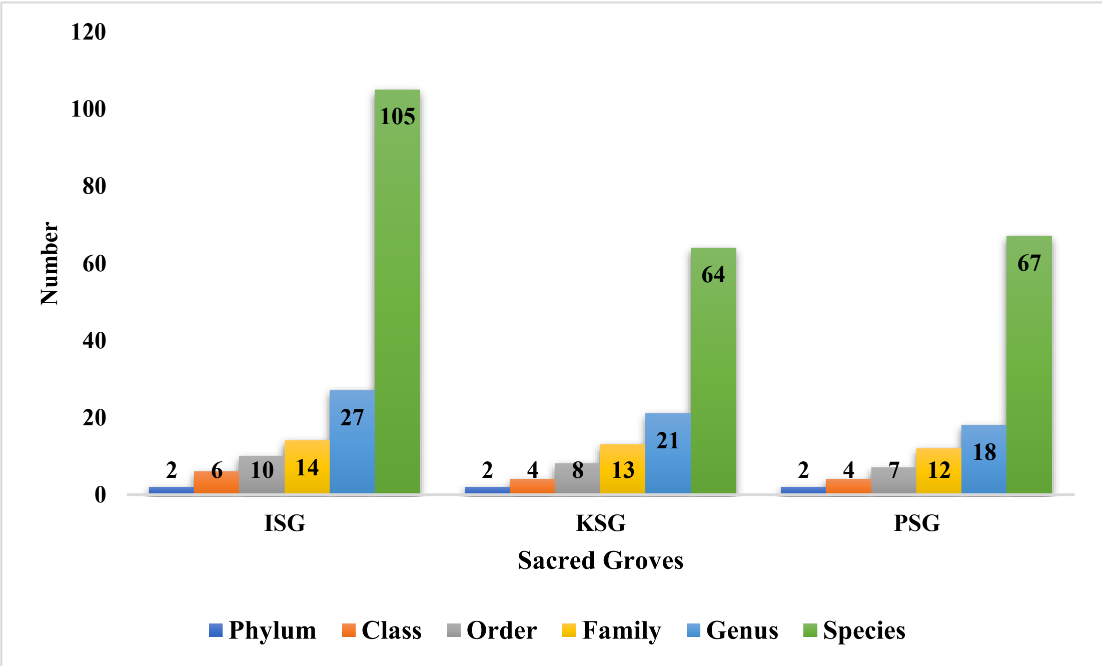

Figure 4. Graph showing the spatial distribution of taxonomic rank

Table 6. Spatial and seasonal distribution of fungal taxa identified from the study area

Sl. No	Species	Iringole Kavu												Kollakal Thapovanam												Poyilkavu											
		Pre 1		Mo 1		Po 1		Pre 2		Mo 2		Po 2		Pre 1		Mo 1		Po 1		Pre 2		Mo 2		P0 2		Pre 1		Mo 1		Po 1		Pre 2		Mo 2		P0 2	
		C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P
1	*Cladosporium cladosporioides*																															+					
2	*Alternaria atra*																						+														
3	*Alternaria tenuissima*							+																													
4	*Aspergillus brevipes*				+				+																												
5	*Aspergillus caesiellus*											+															+										
6	*Aspergillus carneus*											+			+																						
7	*Aspergillus conicus*						+																														
8	*Aspergillus coremiiformis*								+	+		+								+																	
9	*Aspergillus duricaulis*		+						+																	+	+										

10	*Aspergillus flavus*	+	+						+			+	+		+		+	+							+		+				+		+				+
11	*Aspergillus flavus* var. *columnaris*		+																																		
12	*Aspergillus flavus* yellow mutant							+																													
13	*Aspergillus fumigatus*	+	+	+	+							+	+														+										
14	*Aspergillus kanagawaensis*							+																													
15	*Aspergillus koningii*																											+	+								
16	*Aspergillus niger*	+	+			+	+	+	+				+			+			+						+						+		+		+		+
17	*Aspergillus ochraceus*														+																						
18	*Aspergillus petrakii*			+																																	
19	*Aspergillus raperi*				+																																
20	*Aspergillus subalbidus*								+																												
21	*Aspergillus sulphureus*							+													+																

22	*Aspergillus viridinutans*						+																														
23	*Aspergillus* sp. 1								+																												
24	*Aspergillus* sp. 2			+																																	
25	*Aspergillus* sp. 3				+																								+								
26	*Aspergillus* sp. 4	+																																			
27	*Aspergillus* sp. 5											+														+											
28	*Aspergillus* sp. 6											+																									
29	*Aspergillus* sp. 7						+																														
30	*Aspergillus* sp. 8																									+											
31	*Aspergillus* sp. 9							+																													
32	*Aspergillus* sp. 10													+	+																						
33	*Aspergillus* sp. 11		+																																		
34	*Neosartorya quadricincta*													+																							

35	*Paecilomyces stipitatus*									+											+																
36	*Paecilomyces victoriae*																					+	+														
37	*Paecilomyces* sp. 1																													+							
38	*Penicillium adametzii*						+																														
39	*Penicillium aurantiogriseum* var. *aurantiogriseum*			+					+	+													+										+				
40	*Penicillium brevicompactum*										+						+						+									+					
41	*Penicillium capsulatum*							+																													
42	*Penicillium chermesinum*						+					+	+	+																							
43	*Penicillium chrysogenum*			+																								+									

44	*Penicillium citrinum*								+							+		+			+	+		+						+					+	+	+
45	*Penicillium crystallinum*	+																																			
46	*Penicillium cyaneum*					+																															
47	*Penicillium granulatum*							+																									+				
48	*Penicillium janczewskii*																		+																		
49	*Penicillium janthinellum*			+													+						+											+	+		
50	*Penicillium javanicum*																						+														
51	*Penicillium lividum*			+																																	

52	*Penicillium miczynskii*			+				+				+		+																							
53	*Penicillium novae-zeelandiae*																		+																		
54	*Penicillium paxilli*				+																																
55	*Penicillium restrictum*													+																							
56	*Penicillium roqueforti*	+																																			
57	*Penicillium roseopurpureum*						+																														
58	*Penicillium simplicissimum*				+		+					+	+			+			+		+				+												
59	*Penicillium spinulosum*					+	+																														

60	*Penicillium sublateritium*														+																						
61	*Penicillium thomii* var. *thomii*					+					+	+	+																+								
62	*Penicillium velutinum*													+														+									
63	*Penicillium vinaceum*													+																							
64	*Penicillium waksmanii*																													+							
65	*Penicillium* sp. 1													+	+																						
66	*Penicillium* sp. 2																																	+			
67	*Penicillium* sp. 3					+																															
68	*Penicillium* sp. 4																																	+			
69	*Penicillium* sp. 5																																	+			

70	*Penicillium* sp. 6						+																														
71	*Penicillium* sp. 7										+																							+			
72	*Penicillium* sp. 8											+	+															+	+								
73	*Penicillium* sp. 9																											+	+								
74	*Penicillium* sp. 10																																	+			
75	*Penicillium* sp. 11																						+									+	+				
76	*Penicillium* sp. 12																											+	+								
77	*Penicillium* sp. 13							+				+																									
78	*Penicillium* sp. 14												+			+		+		+	+				+												
79	*Penicillium* sp. 15																+		+		+	+		+													
80	*Penicillium* sp. 16							+	+																												
81	*Penicillium* sp. 17									+	+										+													+	+		
82	*Penicillium* sp. 18										+																						+		+		
83	*Penicillium* sp. 19																					+	+												+		

84	*Penicillium* sp. 20							+																													
85	*Penicillium* sp. 21																																	+			
86	*Penicillium* sp. 22																																	+			
87	*Talaromyces aculeatus*			+																										+						+	
88	*Talaromyces atroroseus*							+																													
89	*Talaromyces brunneus*										+																										
90	*Talaromyces diversus*																						+		+												
91	*Talaromyces duclauxii*							+	+	+																							+		+		
92	*Talaromyces flavus*								+							+		+			+																
93	*Talaromyces funiculosus*			+																																	

94	*Talaromyces islandicus*														+																						
95	*Talaromyces piceae*																												+										
96	*Talaromyces purpureogenus*													+										+									+				
97	*Talaromyces variabilis*						+					+																+									
98	*Talaromyces verruculosus*						+					+					+		+											+	+					+	+
99	*Talaromyces* sp. 1																				+																
100	*Talaromyces* sp. 2																					+															
101	*Talaromyces* sp. 3							+																													
102	*Talaromyces* sp. 4																																	+			
103	*Oidiodendron* sp. 1									+																											

104	*Geotrichum candidum*			+																																	
105	*Colletotrichum aotearoa*						+																														
106	*Colletotrichum* sp. 1																						+														
107	*Colletotrichum* sp. 2										+																										
108	*Furcasterigmium furcatum*																						+														
109	*Plectosphaerella cucumerina*					+	+																+														
110	*Plectosphaerella* sp. 1							+																													
111	*Cordyceps farinosa*							+																													
112	*Trichoderma asperelloides*				+																																

113	*Trichoderma hamatum*						+																														
114	*Trichoderma harzianum*			+	+	+			+	+	+	+	+		+	+	+	+		+	+	+	+	+	+							+	+			+	+
115	*Trichoderma spirale*										+																										
116	*Trichoderma virens*													+					+																		
117	*Trichoderma viride*					+	+		+		+		+	+			+						+									+		+	+		
118	*Trichoderma* sp. 1				+								+															+									
119	*Trichoderma* sp. 2										+											+	+														
120	*Trichoderma* sp. 3												+																								
121	*Acremonium implicatum*							+								+				+					+									+	+		
122	*Acremonium* sp. 1																											+									
123	*Acremonium* sp. 2									+													+	+									+				

124	*Acremonium* sp. 3																+					+		+				+									
125	*Acremonium* sp. 4																	+					+														
126	*Gliomastix murorum*											+																									
127	*Gliomastix roseogrisea*														+																						
128	*Gliomastix* sp. 1												+																								
129	*Sarocladium gamsii*																				+																
130	*Sarocladium hominis*										+																							+		+	
131	*Sarocladium kiliense*	+								+	+																						+				
132	*Sarocladium* sp. 1																					+															
133	*Cosmospora butyri*								+																												
134	*Fusarium oxysporum*		+																																		

135	*Fusarium tricinctum*							+								+						+		+										+			
136	*Fusarium verticillioides*																													+							
137	*Fusarium* sp. 1							+										+																			
138	*Fusarium* sp. 2																																	+			
139	*Mariannaea* sp. 1																											+									
140	*Neocosmospora solani*	+							+																												
141	*Purpureocillium lilacinum*	+		+	+		+	+	+	+		+	+			+		+			+	+	+		+	+		+			+			+	+	+	+
142	*Purpureocillium lilacinum* natural mutant			+																																	
143	*Cephalotrichum asperulum*							+	+																												

144	*Microascus atrogriseus*													+																							
145	*Microascus* sp. 1										+																										
146	*Scedosporium apiospermum*								+																												
147	*Scedosporium* sp. 1										+																										
148	*Scopulariopsis asperula*						+																														
149	*Scopulariopsis brevicaulis*																				+																
150	*Scopulariopsis candida*																														+						
151	*Scopulariopsis* sp. 1										+																										
152	*Wardomyces inflatus*																																	+			

153	*Chloridium guttiferum*																																	+		
154	*Chloridium* sp. 1																+					+														
155	*Chloridium* sp. 2									+																										
156	*Sirococcus tsugae*								+																											
157	*Trichocladium* sp. 1																				+	+		+												
158	*Trichocladium* sp. 2																																+			
159	*Absidia cylindrospora*				+																															
160	*Gongronella butleri*			+	+																						+			+						
161	*Gongronella* sp. 1																												+	+					+	
162	*Gongronella* sp. 2														+			+		+							+	+								
163	*Rhizomucor pusillus*																												+					+		
164	*Mucor bacilliformis*																												+							

165	*Mucor circinelloides*						+	+	+	+	+		+			+		+			+	+	+					+	+			+	+	+			
166	*Mucor hiemalis* f. *corticola*																							+									+				
167	*Mucor hiemalis* f. *hiemalis*									+	+			+											+								+	+			
168	*Mucor mucedo*													+	+		+		+																		
169	NSF 1																				+			+													
170	NSF 2											+																									
171	Unknown 1				+																																
172	Unknown 2											+																									
173	Unknown 3										+																										
174	Unknown 4																																		+		

The seasonal distribution of fungi by species is depicted in Figure 5. The number of species varies across different seasons. Iringole Kavu has the highest number of species in the Pre 2 season, while Kollakal Thapovanam and Poyilkavu exhibit the largest numbers in the Mo 2 season.

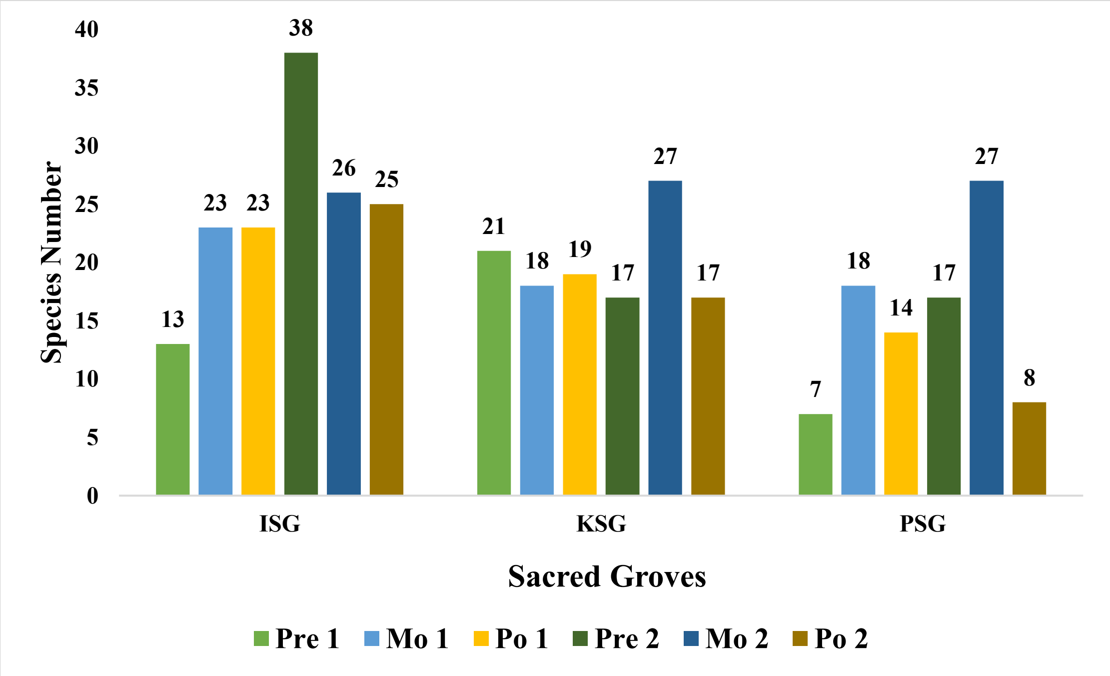

Figure 5. Graph showing the seasonal distribution of species

Venn diagrams were created for each taxonomic level (Figure 6). These diagrams illustrate the similarities and differences in taxonomic ranks among the three sacred groves. A total of 16 species were common to all three groves. Additionally, 18 species were exclusively found in both Iringole Kavu and Poyilkavu, while 12 were unique to the combination of Iringole Kavu and Kollakal Thapovanam. There were also 7 species found only in Poyilkavu and Kollakal Thapovanam. Moreover, 59 species were found exclusively in Iringole Kavu, 29 were unique to Kollakal Thapovanam, and 26 were found only in Poyilkavu.

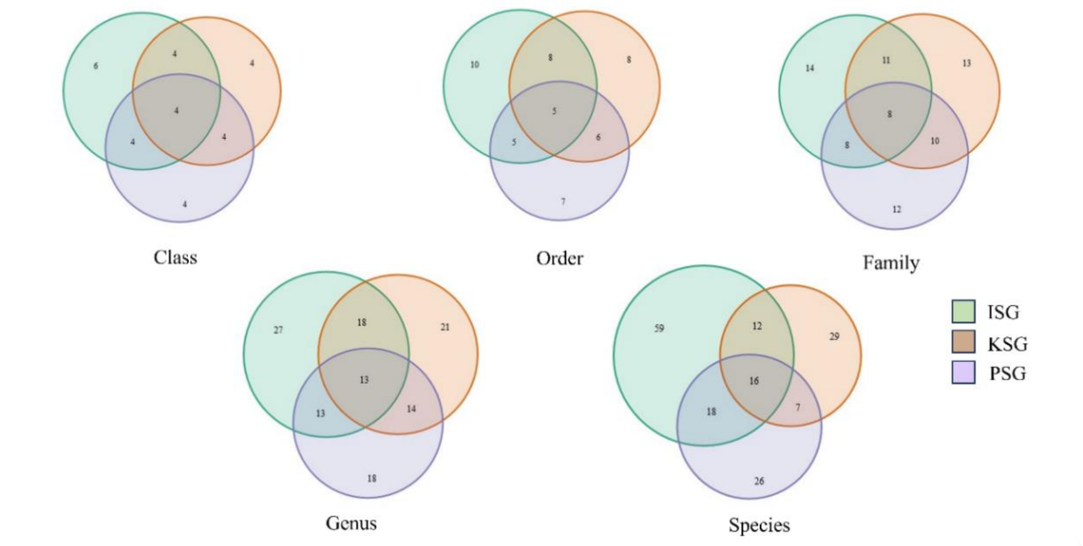

Figure 6. Venn diagram at different taxonomic levels

Table 7 displays the genera that were identified exclusively in sacred groves, while Table 8 lists the species that were found to be abundant across the study area. In total, 8 genera were found only in Iringole Kavu, 2 genera were specific to Kollakal Thapovanam, and 4 genera were unique to Poyilkavu. Additionally, 14 species were abundant throughout the entire study.

Table 7. List of genera found only in a sacred grove

Iringole Kavu	Kollakal Thapovanam	Poyilkavu
Oidiodendron	*Neosartorya*	*Cladosporium*
Geotrichum	*Furcasterigmium*	*Mariannae*
Cordyceps		*Wardomyces*
Cosmospora		*Rhizomucor*
Neocosmospora		
Cephalotrichum		
Scedosporium		
Sirococcus		

Table 8. List of abundant species

1	*Purpureocillium lilacinum*	9	*Talaromyces verruculosus*
2	*Trichoderma harzianum*	10	*Penicillium aurantiogriseum* var. *aurantiogriseum*
3	*Aspergillus flavus*	11	*Penicillium* sp. 15
4	*Aspergillus niger*	12	*Acremonium implicatum*
5	*Mucor circinelloides*	13	*Fusarium tricinctum*
6	*Penicillium citrinum*	14	*Mucor hiemalis* f. *hiemalis*
7	*Trichoderma viride*		
8	*Penicillium simplicissimum*		

Figure 7 shows spatial and seasonal variation in the number of fungi. The number of fungi shows great variation between sacred groves and across seasons in a sacred grove (Annexure 1–3).

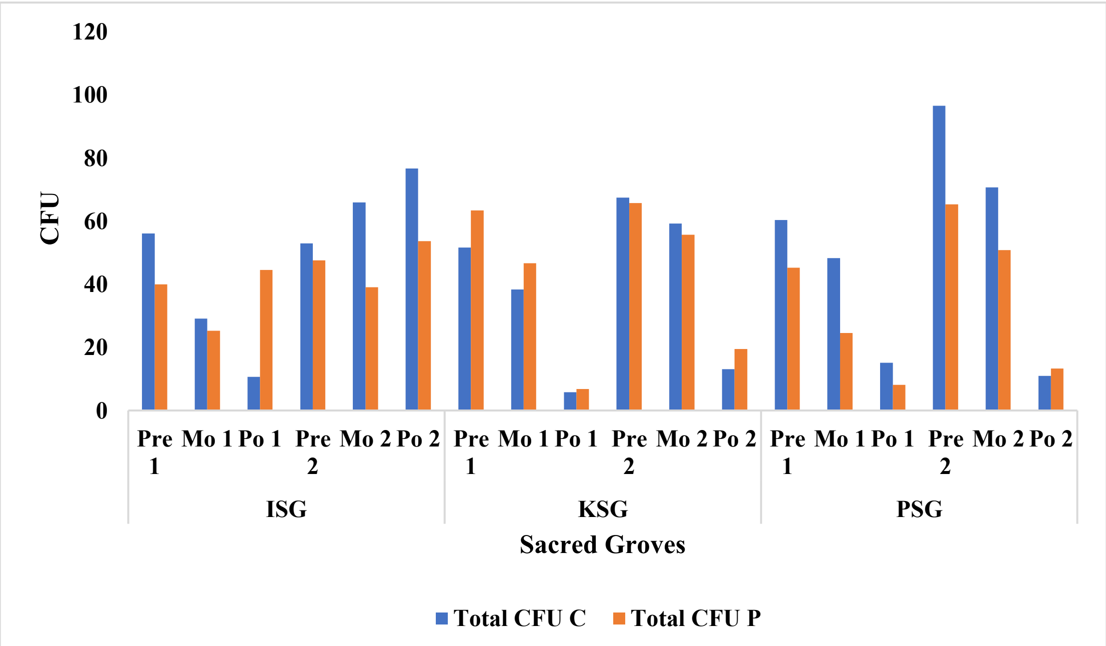

Figure 7. Graph showing the spatial and seasonal variation in the number of fungi

4. 3 Diversity Analysis

A comprehensive analysis of both spatial and seasonal diversity was conducted. Alpha diversity indices, including Chao 1, Simpson's dominance index, Shannon-Wiener index, Pielou's Evenness index, and Margalef Richness index, were calculated. Spatial-wise diversity analysis was conducted (Table 9). Iringole Kavu exhibited the highest values across all the indices studied in this analysis.

Table 9. Spatial diversity study

	ISG		KSG		PSG	
	C	**P**	**C**	**P**	**C**	**P**
Chao-1	67	68	41	51	50	38
Simpson's Dominance Index	0.9496	0.9538	0.8994	0.9508	0.8935	0.917
Shannon-Weriner Index	3.597	3.663	3.002	3.479	2.863	3.016
Pielou's Evenness Index	0.5445	0.5735	0.4911	0.636	0.3503	0.5373
Margalef Richness Index	11.98	12.61	7.429	9.194	8.702	7.052

In the season-wise diversity analysis of Iringole Kavu (Table 10), the Simpson dominance index, Shannon-Wiener index, and Margalef richness index were highest during the Pre 2 season. This indicates a high level of dominance, diversity, and species richness during that period. Conversely, Pielou's evenness index peaked in the Mo 2 season, suggesting a greater balance in species distribution at that time.

For Kollakal Thapovanam (Table 11), the Simpson's dominance index was highest in the Mo 1 season, indicating that the community was dominated by a few species. The Shannon-Wiener index reached its peak in the Mo 2 season, reflecting rich biodiversity during that period. Both Pielou's evenness and Margalef richness indices were highest in the Po 2 season, highlighting both species richness and an equitable distribution of individuals among different species.

In Poyilkavu (Table 12), both the Simpson's dominance and Shannon-Wiener indices were elevated in the Mo 1 season, which signifies high dominance and rich biodiversity - indicating that the first monsoon season is not characterized by a few dominant species. Pielou's evenness index was at its highest in the Po 2 season, which shows that species were evenly abundant at that time. The Margalef richness index was highest in the Mo 2 season, reflecting a significant presence of various species.

Table 10. Seasonal diversity study in Iringole Kavu

ISG		Chao-1	Simpson's Dominance Index	Shannon - Weiner Index	Pielou's Evenness Index	Margalef Richness Index
Pre 1	**C**	9	0.7406	1.63	0.5671	2.035
	P	7	0.732	1.538	0.6648	1.674
Pre 2	**C**	23	0.923	2.808	0.7206	6.093
	P	21	0.9196	2.762	0.7538	6.002
Mo 1	**C**	15	0.9067	2.546	0.8503	5.17
	P	13	0.896	2.401	0.8485	3.728
Mo 2	**C**	13	0.8823	2.347	0.8045	2.943
	P	19	0.8638	2.459	0.6157	5.823
Po 1	**C**	8	0.7535	1.688	0.6763	3.597
	P	19	0.8866	2.542	0.669	5.242
Po 2	**C**	20	0.8012	2.054	0.3901	4.569
	P	15	0.8305	2.131	0.5616	3.7

Table 11. Seasonal diversity study in Kollakal Thapovanam

KSG		Chao-1	Simpson's Dominance Index	Shannon-Weiner Index	Pielou's Evenness Index	Margalef Richness Index
Pre 1	**C**	14	0.8384	2.192	0.6395	3.376
	P	10	0.7633	1.742	0.5711	2.198
Pre 2	**C**	4	0.2497	0.5446	0.431	0.716

	P	16	0.849	2.341	0.6494	3.726
Mo 1	C	11	0.8847	2.269	0.879	2.86
	P	9	0.8776	2.144	0.9481	2.14
Mo 2	C	13	0.8711	2.271	0.7452	3.067
	P	21	0.9412	2.935	0.896	5.317
Po 1	C	10	0.8698	2.16	0.8669	0
	P	9	0.8704	2.113	0.9195	11.54
Po 2	C	9	0.872	2.119	0.925	3.847
	P	10	0.864	2.137	0.8474	3.41

Table 12. Seasonal diversity study in Poyilkavu

PSG		Chao-1	Simpson's Dominance Index	Shannon - Weiner Index	Pielou's Evenness Index	Margalef Richness Index
Pre 1	C	4	0.2296	0.4576	0.3951	0.7388
	P	4	0.2499	0.5252	0.4227	0.7928
Pre 2	C	6	0.6352	1.277	0.5978	1.101
	P	14	0.7095	1.725	0.4009	3.126
Mo 1	C	16	0.8967	2.494	0.7567	3.964
	P	8	0.8178	1.894	0.831	2.299
Mo 2	C	20	0.6473	1.705	0.2752	4.66
	P	13	0.8622	2.255	0.7335	3.19
Po 1	C	9	0.7635	1.771	0.6532	3.119

	P	7	0.7851	1.72	0.7979	3.728
Po 2	**C**	6	0.7543	1.564	0.7966	2.404
	P	6	0.7474	1.563	0.7953	2.171

The Bray-Curtis similarity index, which measures beta diversity, was calculated for each site. Results are summarized in Table 13.

Table 13. Bray-Curtis similarity index

	ISG C	**ISG P**	**KSG C**	**KSG P**	**PSG C**	**PSG P**
ISG C	1	0.92349	0.89393	0.93873	0.98225	0.83131
ISG P	0.92349	1	0.9702	0.98469	0.90587	0.90661
KSG C	0.89393	0.9702	1	0.95491	0.87642	0.93623
KSG P	0.93873	0.98469	0.95491	1	0.92107	0.89145
PSG C	0.98225	0.90587	0.87642	0.92107	1	0.81412
PSG P	0.83131	0.90661	0.93623	0.89145	0.81412	1

4.4 Multivariate Analysis

4.4.1 Hierarchical Cluster Analysis (HCA)

Hierarchical Cluster Analysis (HCA) based on the Bray-Curtis method was conducted to assess similarities among sites and seasons. The outcomes are presented as a dendrogram. The dendrogram (Figure 8) representing spatial similarity shows two distinct groups: Iringole Kavu and Poyilkavu fall into the first group, while Kollakal Thapovanam stands alone as a separate group.

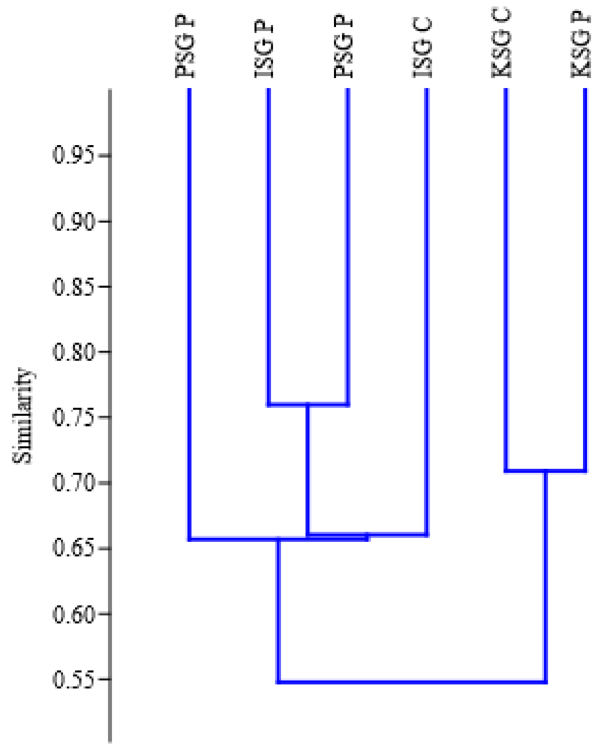

Figure 8. Dendrogram of Hierarchical Cluster Analysis showing spatial similarity

In terms of seasonal similarity for Iringole Kavu, the dendrogram (Figure 9) reveals two groups. The first group is further divided into two subgroups: the first subgroup consists of Pre 2, Mo 1, and Po 1, while the second subgroup includes Mo 2 and Po 2. Pre 1 is identified as a separate group.

Similarly, the dendrogram (Figure 10) indicating seasonal similarity for Kollakal Thapovanam also forms two groups. In this case, the post-monsoon season is separate, whereas the pre-monsoon and monsoon seasons are grouped together.

Lastly, the dendrogram (Figure 11) illustrating seasonal similarity for Poyilkavu shows two groups as well. Here, the first group is subdivided into two subgroups: Pre 2, Mo 1, and Mo 2 form the first subgroup, while the post-monsoon season constitutes the second subgroup. Pre 1 is again classified as a separate group.

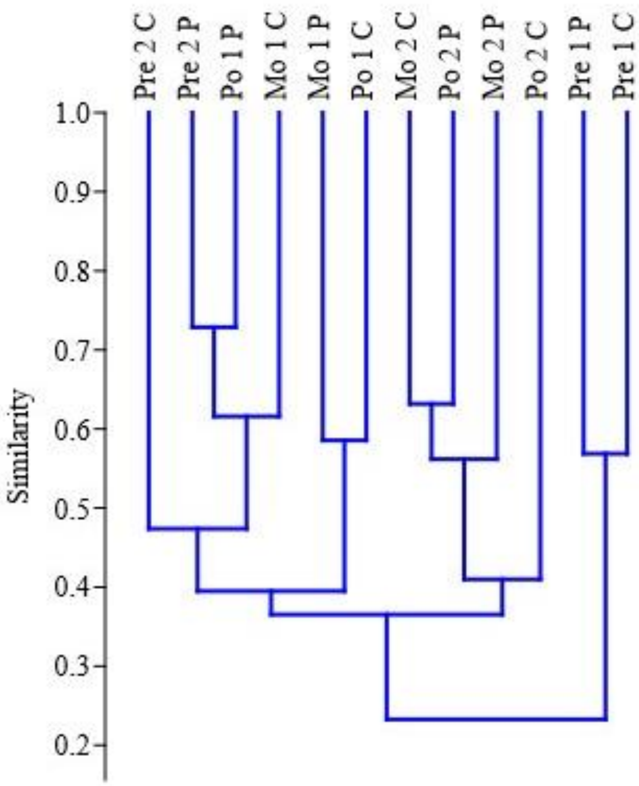

Figure 9. Dendrogram of Hierarchical Cluster Analysis showing seasonal similarity of Iringole Kavu

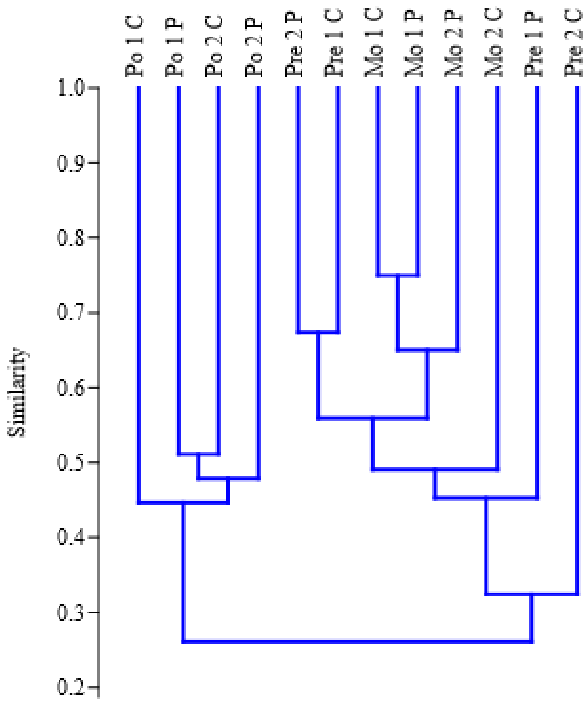

Figure 10. Dendrogram of Hierarchical Cluster Analysis showing seasonal similarity of Kollakal Thapovanam

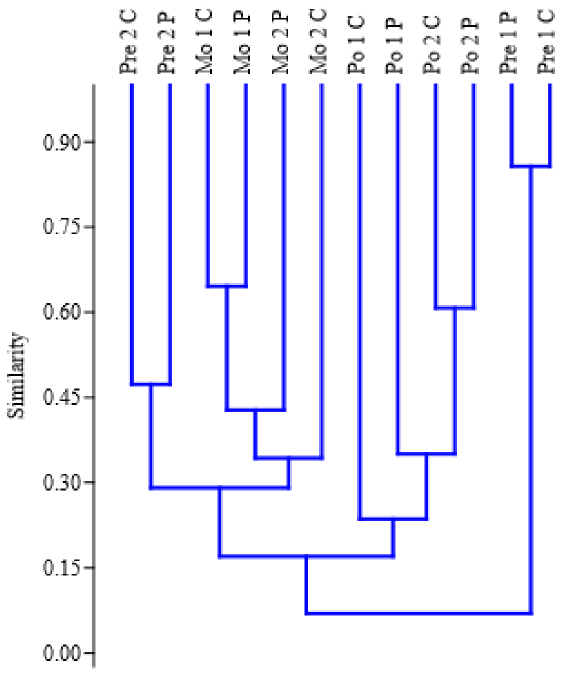

Figure 11. Dendrogram of Hierarchical Cluster Analysis showing seasonal similarity of Poyilkavu

4.4.2 Non-metric Multidimensional Scaling (NMDS) Analysis

Non-metric multidimensional scaling (NMDS) analysis provides a 2D plot that displays sites or seasons with similar species distributions arranged closely together. NMDS analysis was done across sites and seasons. The NMDS analysis, shown in Figure 12, illustrates spatial similarities and dissimilarities among the sites. Each sacred grove stands apart, highlighting its uniqueness and distinct flora.

The NMDS analysis shown in Figure 13 highlights the seasonal similarities and differences in Iringole Kavu. The data points representing the pre-monsoon season are distinctly separate, indicating a unique floral composition. In contrast, the points for the monsoon and post-monsoon seasons are closely clustered, suggesting that these two seasons share similar fungal compositions.

In Kollakal Thapovanam, as depicted in Figure 14, the post-monsoon points are set apart from those of the other seasons, while the pre-monsoon and monsoon points cluster together. This separation indicates that the post-monsoon flora is distinct across both years, whereas the monsoon and pre-monsoon seasons have similar floral compositions.

For Poyilkavu, the NMDS analysis reveals that the flora for each season is different and unique, as the points representing each season are positioned far apart (Figure 15). These findings from the NMDS analysis align with the results of the Hierarchical Cluster Analysis.

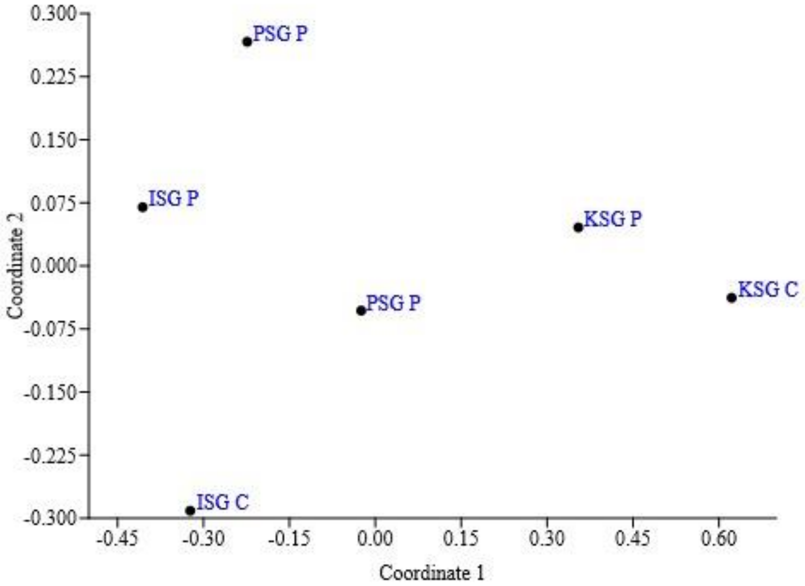

Figure 12. Scatter plot of Non-metric Multidimensional Scaling analysis across sites

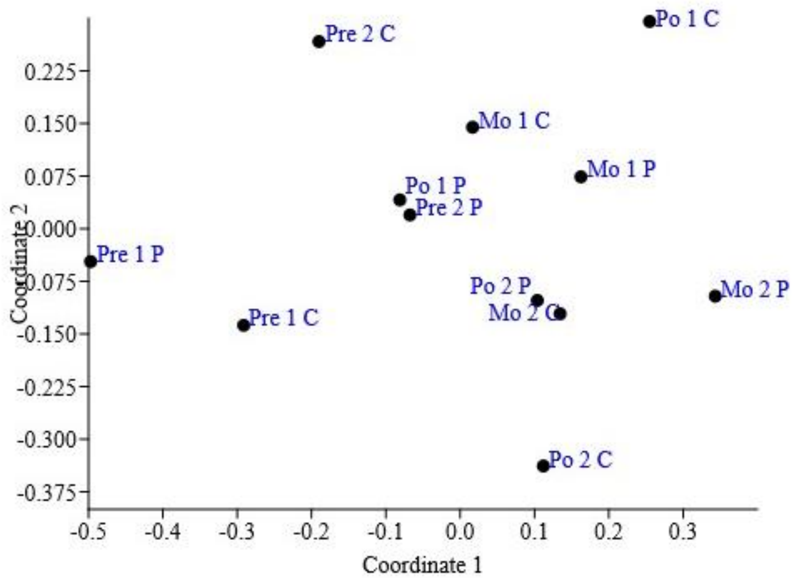

Figure 13. Scatter plot of Non-metric Multidimensional Scaling analysis across seasons in Iringole Kavu

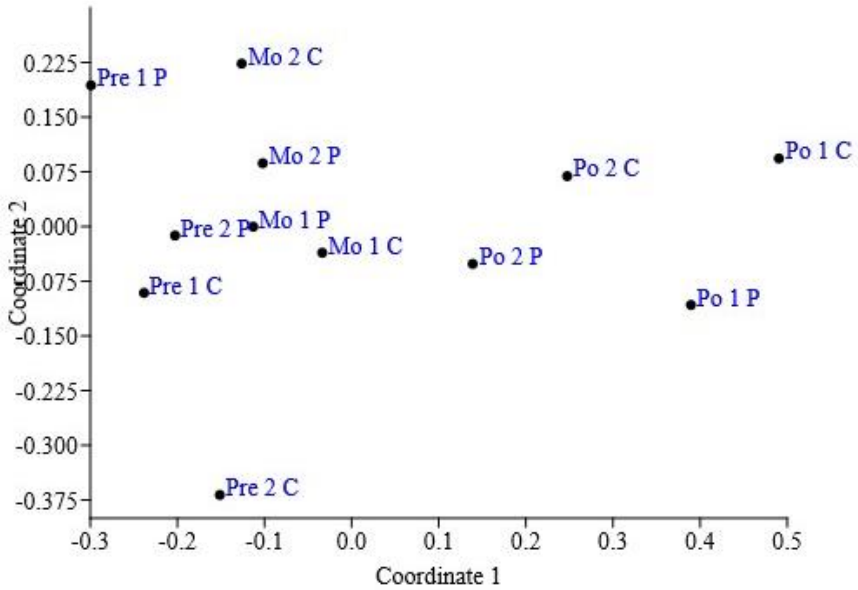

Figure 14. Scatter plot of Non-metric Multidimensional Scaling analysis across seasons in Kollakal Thapovanam

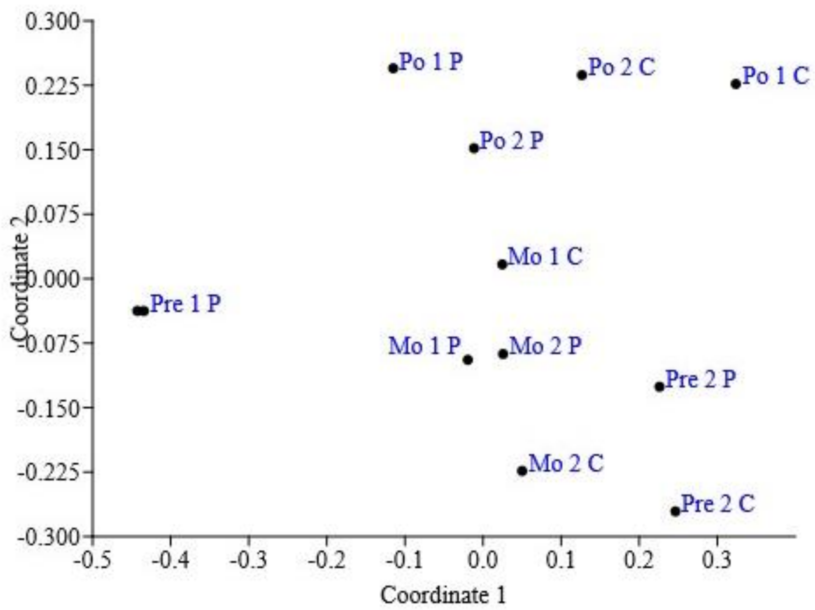

Figure 15. Scatter plot of Non-metric Multidimensional Scaling analysis across seasons in Poyilkavu

4.5 Physicochemical Analysis of Soil

A total of twelve physicochemical parameters were analysed over three seasons for two years. These parameters include Temperature, pH, Moisture Content, Organic Carbon, Electrical Conductivity, Water Holding Capacity, Available Nitrogen, Available Phosphorus, Available Potassium, Exchangeable Calcium, Exchangeable Sodium, and Soil Texture. The Mean and Standard Deviation, computed from the recorded values, are shown in the table (Annexure 4).

Pearson's correlation coefficient was calculated at the same significance level to determine the relationships between different parameters (Annexure 5–7). In the correlation plot, large blue circles indicate a positive correlation, while large red circles signify a negative correlation.

In Iringole Kavu, temperature shows a significant positive correlation with available nitrogen, while it is negatively correlated with exchangeable calcium and organic carbon. pH is significantly positively correlated with water holding capacity and also positively correlated with moisture content. Moisture content exhibits a significant positive correlation with electrical conductivity, but it is negatively correlated with exchangeable sodium. Organic carbon is positively correlated with available potassium and exchangeable calcium, but negatively correlated with temperature, electrical conductivity, and available nitrogen. Electrical conductivity is strongly positively correlated with moisture content, while it shows a negative correlation with organic carbon and exchangeable calcium. Water holding capacity has a significant positive correlation with pH, but is strongly negatively correlated with available potassium and available nitrogen. Available nitrogen is significantly correlated with temperature, while it is strongly negatively correlated with exchangeable calcium, available phosphorus, and water holding capacity. Available phosphorus shows a significant positive correlation with exchangeable sodium, while it is negatively correlated with available nitrogen. Available potassium has a positive correlation with organic carbon and available nitrogen, but it is strongly negatively correlated with water holding capacity. Exchangeable calcium is negatively correlated with temperature and available nitrogen but positively correlated with organic carbon. Lastly, exchangeable sodium is strongly positively correlated with available phosphorus while showing a negative correlation with moisture content (Figure 16).

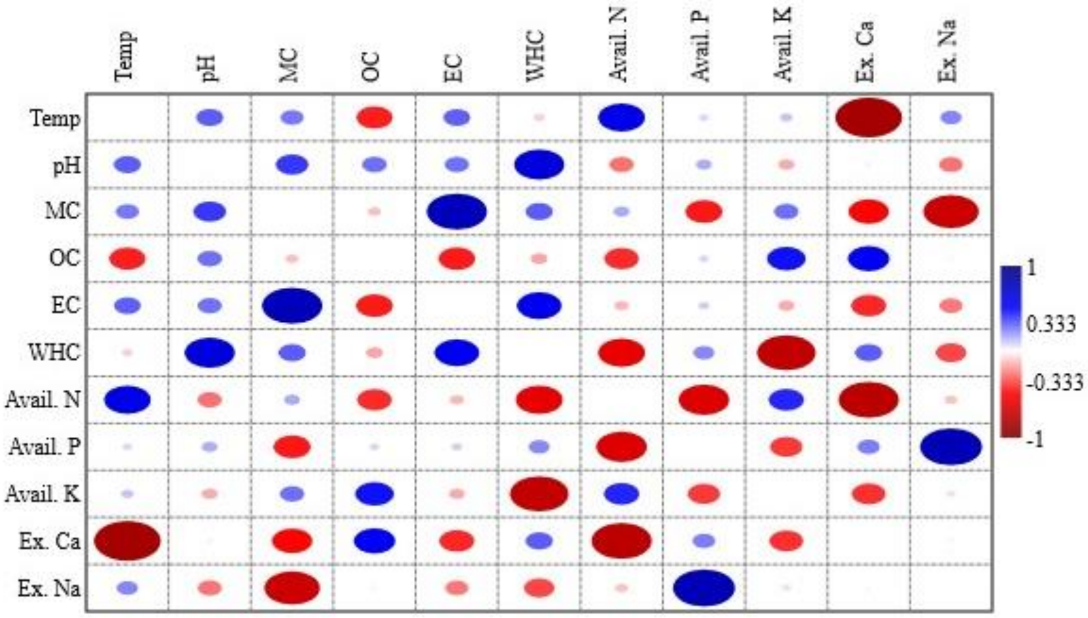

Figure 16. Correlation plot of parameters analysed seasonally from Iringole Kavu

In Kollakal Thapovanam, temperature exhibits a positive correlation with water-holding capacity, available phosphorus, and exchangeable sodium. Conversely, it has a negative correlation with pH. pH is strongly negatively correlated with water-holding capacity and shows a negative correlation with temperature and available nitrogen, while it has a slight positive correlation with exchangeable calcium. Moisture content is positively correlated with electrical conductivity and organic carbon but negatively correlated with exchangeable calcium, available potassium, and available phosphorus. Organic carbon has a significant positive correlation with electrical conductivity and is also positively correlated with available phosphorus and moisture content. However, it shows a negative correlation with exchangeable calcium and sodium. Electrical conductivity is positively correlated with moisture content and available phosphorus, and it has a strong positive correlation with organic carbon. Water holding capacity is positively correlated with temperature and available phosphorus, but negatively correlated with pH. Available nitrogen shows only a slight correlation with other parameters. Available phosphorus is positively correlated with temperature, organic carbon, electrical conductivity, and water-holding capacity. Available potassium is negatively correlated with moisture content and does not show any significant positive correlation with other parameters. Exchangeable calcium has a significant positive correlation with exchangeable sodium but is negatively correlated with moisture content and organic carbon. Exchangeable sodium is strongly positively correlated with exchangeable calcium while negatively correlated with moisture content and organic carbon (Figure 17).

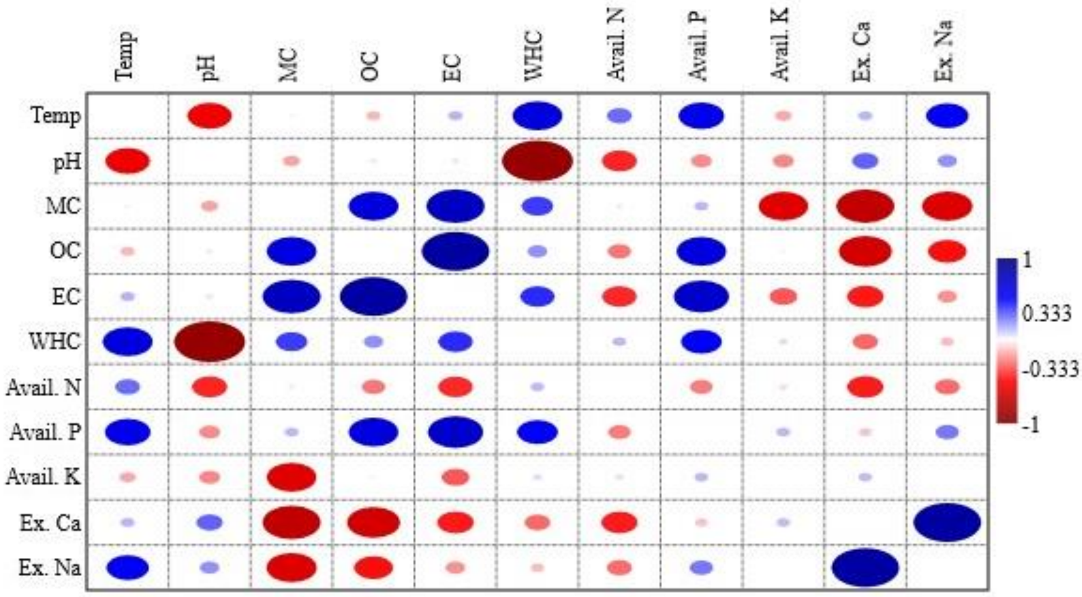

Figure 17. Correlation plot of parameters analysed seasonally from Kollakal Thapovanam

In Poyilkavu, the temperature shows a positive correlation with pH, available nitrogen, exchangeable calcium, and exchangeable sodium. In addition, pH is positively correlated with temperature, exchangeable calcium, and exchangeable sodium, while it has a negative correlation with electrical conductivity and available nitrogen. Moisture content is positively correlated with electrical conductivity and water holding capacity, whereas it exhibits a strong negative correlation with exchangeable calcium and exchangeable sodium. Organic carbon displays a significant positive correlation with water holding capacity, available phosphorus, and available potassium, but it is strongly negatively correlated with available nitrogen. Electrical conductivity has a positive correlation with water holding capacity, but it is negatively correlated with pH. Water holding capacity shows a strong positive correlation with organic carbon, electrical conductivity, and available phosphorus, while it has a strong negative correlation with available nitrogen. Available nitrogen is slightly positively correlated with temperature, but it has strong negative correlations with organic carbon, available phosphorus, and water holding capacity. Available phosphorus is positively correlated with organic carbon and water holding capacity, while it is strongly negatively correlated with available nitrogen. Available potassium shows a positive correlation with available phosphorus, as well as a significant positive correlation with organic carbon. Exchangeable calcium is positively correlated with temperature, pH, and available phosphorus, while it has a strong positive correlation with exchangeable sodium. However, it is negatively correlated with moisture content. Exchangeable sodium is positively correlated with temperature, pH, and available potassium, and it has a strong positive correlation with exchangeable calcium. It also shows a negative correlation with moisture content (Figure 18).

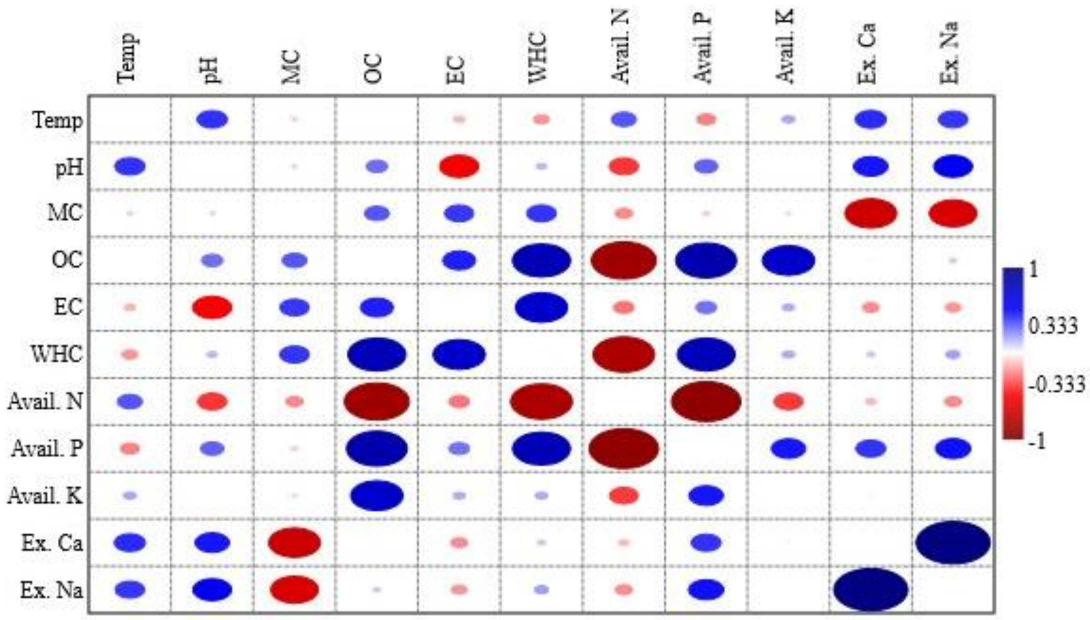

Figure 18. Correlation plot of parameters analysed seasonally from Poyilkavu

4.5.1 Temperature

The temperature in the study area ranges from 20 to 28.87°C. Figure 19 analyses spatial and seasonal variations in temperature. Overall, the temperature range is quite similar across all three sacred groves. Seasonally, the pre-monsoon period exhibits the highest mean temperatures in all three sacred groves, while the post-monsoon period shows the lowest mean temperatures. Specifically, the minimum mean temperature is recorded at Po 1 of Iringole Kavu (20 ±0.4°C), and the maximum is at Pre 1 of Kollakal Thapovanam (28.87 ±0.25°C). The one-way ANOVA results indicate significant differences in average temperature across the various seasons in all three sacred groves ($p < 0.05$) (Annexure 8–10).

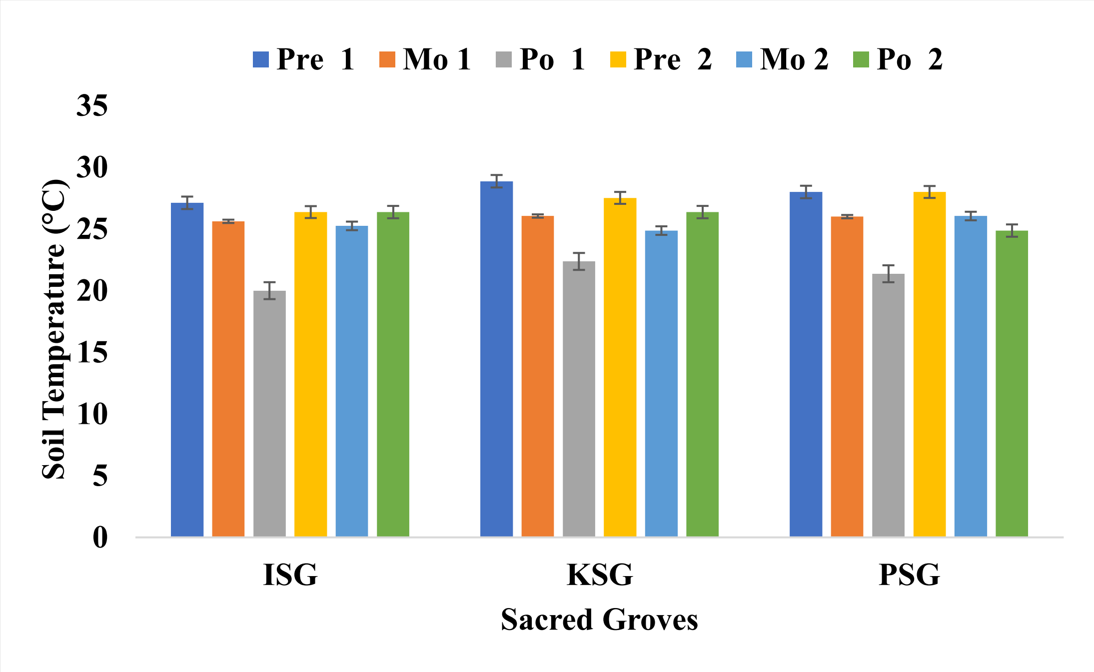

Figure 19. Graph showing the spatial and seasonal variation of soil temperature in the study area

4.5.2 pH

The pH levels in the study area range from 4.35 to 5.86. Figure 20 illustrates the spatial and seasonal variations in pH across different locations. The pH levels are quite similar among all the sacred groves. Seasonally, the highest pH values are observed at Po 2 in ISG, Po 1 in KSG, and Mo 1 in PSG, while the lowest mean pH values occur at Mo 1 of ISG, Pre 2 of KSG, and Po 2 of PSG. The minimum mean pH is recorded at Po 2 of Poyilkavu (4.35 ±0.92), whereas the maximum is found at Po 2 of Iringole Kavu (5.86 ±0.25). The one-way ANOVA results indicate significant differences in average pH across the various seasons in all three sacred groves ($p < 0.05$) (Annexure 11–13).

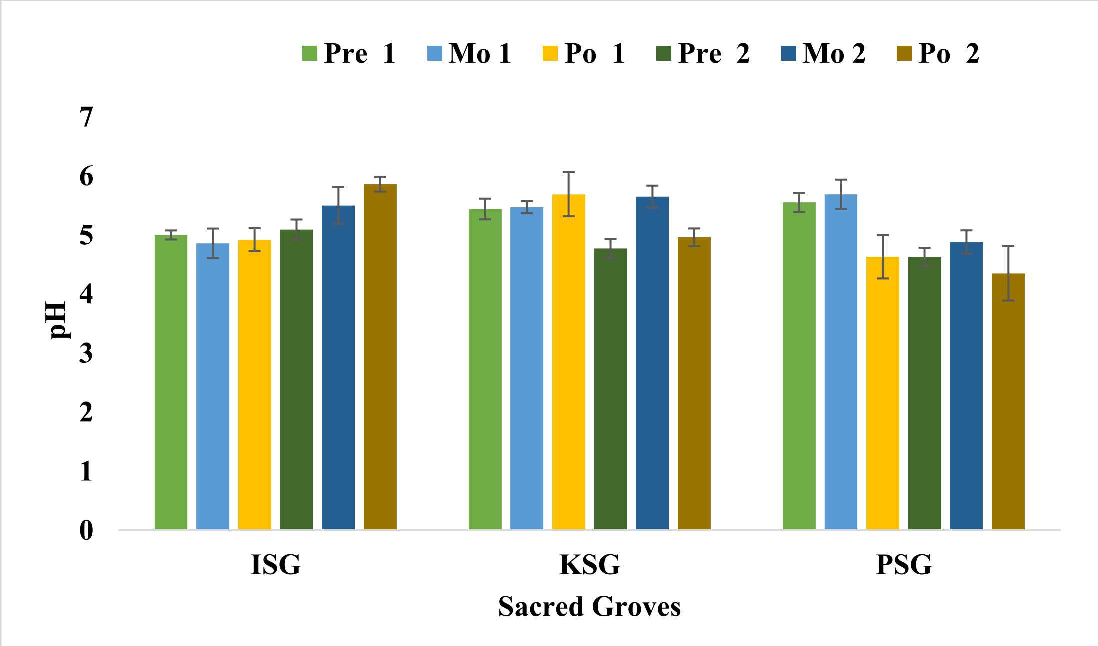

Figure 20. Graph showing the spatial and seasonal variation of soil pH in the study area

4.5.3 Moisture Content

The moisture content levels in the study area range from 1.72% to 23.35%. Figure 21 illustrates the spatial and seasonal variations in moisture content across different locations. Notably, Iringole Kavu has the highest moisture content. Seasonal trends indicate that monsoon 1 exhibits high moisture content across all sacred groves, while pre-monsoon 1 registers the lowest levels. The minimum mean moisture content is recorded at Pre 1 of Kollakal Thapovanam, measuring 1.72% ±0.21, whereas the maximum is found at Mo 1 of Iringole Kavu, at 23.35% ±8.69. The one-way ANOVA results indicate significant differences in average moisture content across the various seasons in all three sacred groves ($p < 0.05$) (Annexure 14–16).

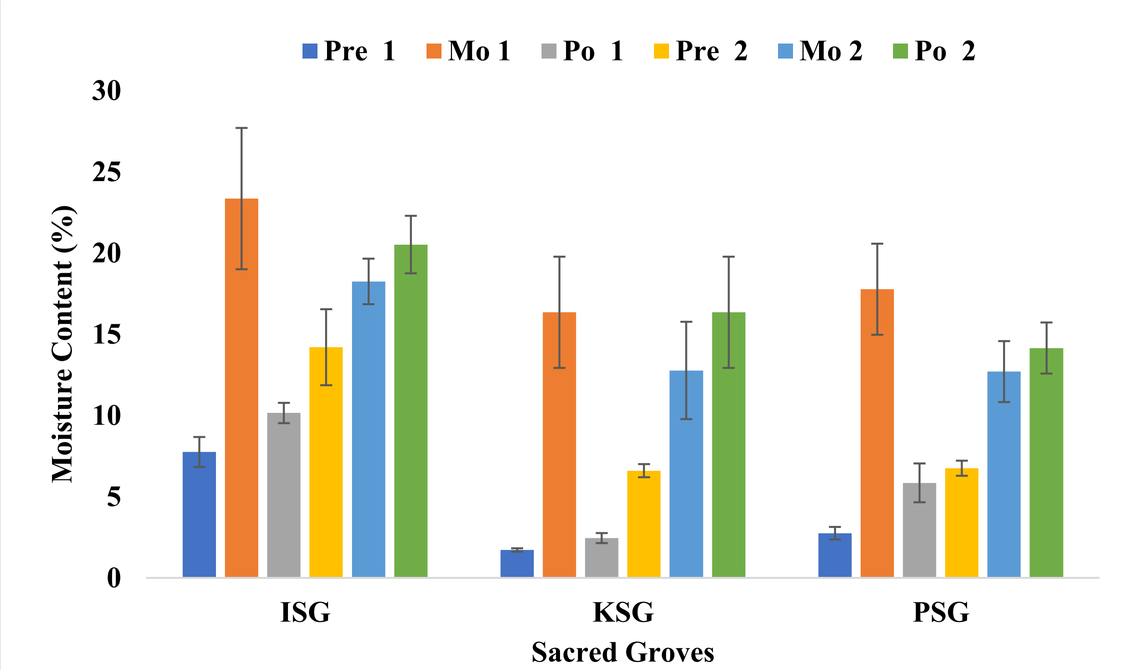

Figure 21. Graph showing the spatial and seasonal variation of moisture content in the study area

4.5.4 Organic Carbon

The organic carbon levels in the study area range from 0.35% to 2.32%. Figure 22 illustrates the spatial and seasonal variations of organic carbon across different locations. There is significant variation in organic carbon both spatially and seasonally. Iringole Kavu shows the highest organic carbon levels, followed by Poyilkavu, while Kollakal Thapovanam demonstrates significantly low levels. Seasonally, the highest organic carbon values are observed at Mo 2 in ISG and Mo 1 in KSG and PSG. In contrast, the lowest mean organic carbon values are recorded at Pre 2 of ISG, Pre 1 of KSG, and Mo 2 of PSG. The minimum mean organic carbon was observed at Pre 1 of Kollakal Thapovanam (0.35 ±0.23), and the maximum was found at Mo 2 of Iringole Kavu (2.32 ±0.6). The results of the one-way ANOVA indicate that there are no significant differences in average organic carbon levels across the different seasons in Iringole Kavu and Poyilkavu ($p \geq 0.05$). In contrast, Kollakal Thapovanam shows significant differences in average organic carbon levels across the various seasons ($p < 0.05$) (Annexure 17–19).

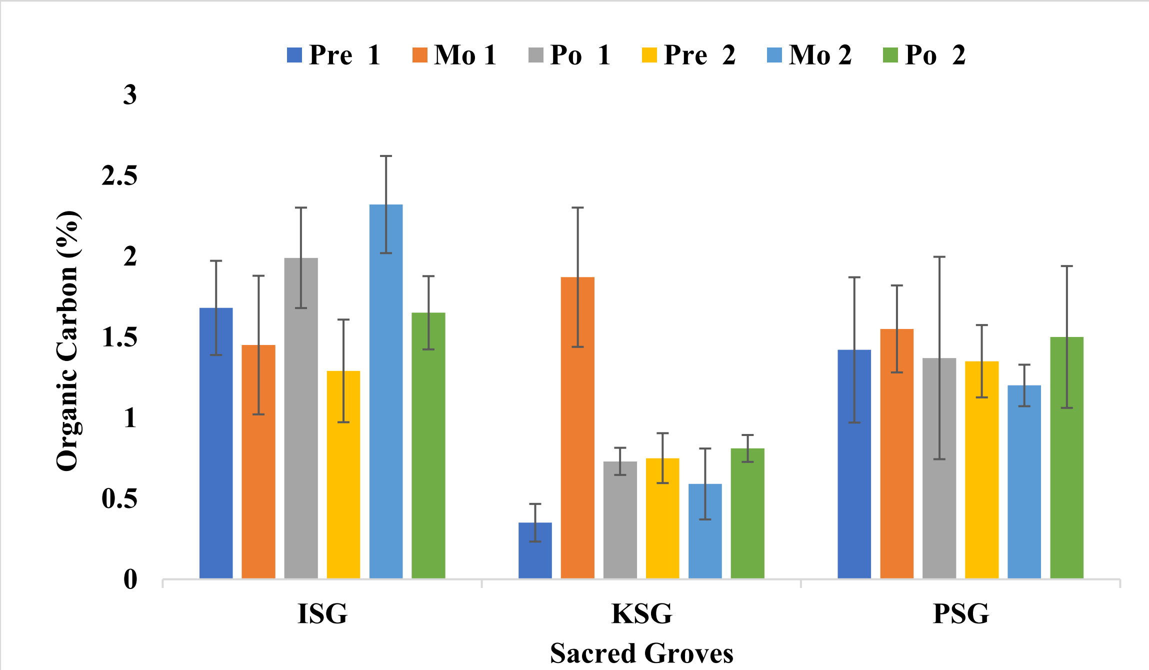

Figure 22. Graph showing the spatial and seasonal variation of organic carbon in the study area

4.5.5 Electrical Conductivity

The electrical conductivity levels in the study area range from 0.01 dS/m to 0.44 dS/m. Figure 23 illustrates the spatial and seasonal variations in electrical conductivity across different locations. The electrical conductivity values in all the sacred groves are negligible. Among the sites, Po 2 of Poyilkavu shows a slightly higher value compared to the others. The lowest mean electrical conductivity is recorded at Po 1 of Kollakal Thapovanam (0.01 ±0.005), while the highest is found at Po 2 of Poyilkavu (0.44 ±0.19). The one-way ANOVA results indicate significant differences in average electrical conductivity levels across various seasons ($p < 0.05$) (Annexure 20–22).

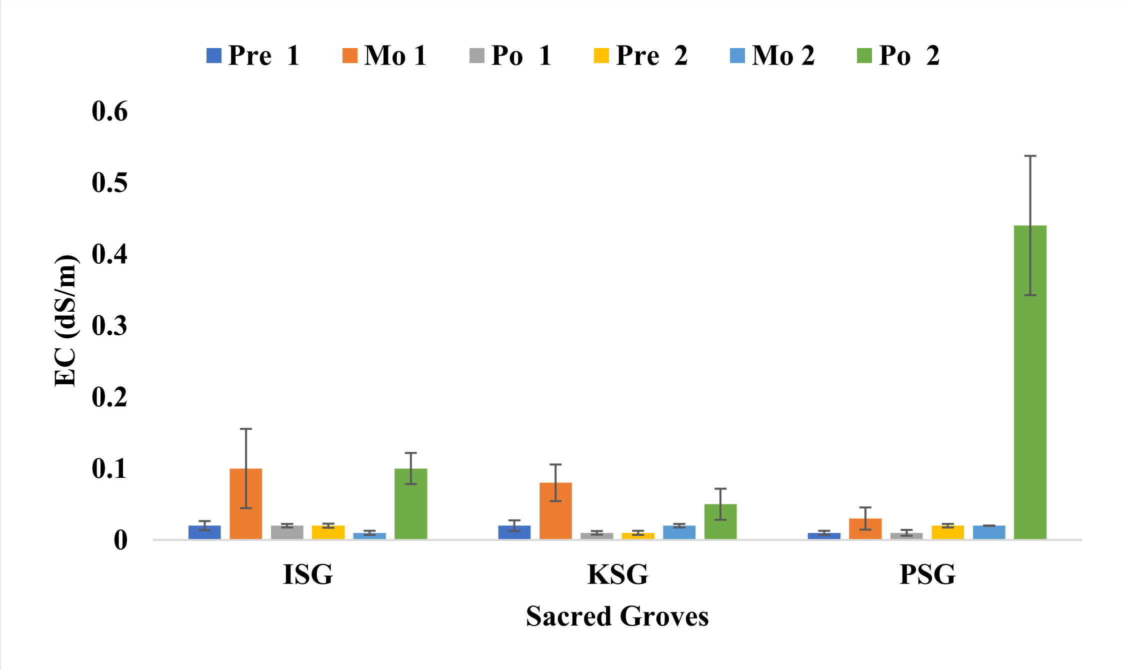

Figure 23. Graph showing the spatial and seasonal variation of electrical conductivity in the study area

4.5.6 Water Holding Capacity

The water holding capacity levels in the study area range from 16.99% to 52.29%. Figure 24 illustrates the spatial and seasonal variations in water holding capacity across different locations. Iringole Kavu exhibits the highest water holding capacity, followed by Poyilkavu and Kollakal Thapovanam. Seasonally, the highest water holding capacity is observed in the second post-monsoon period, while the lowest mean water holding capacity values are recorded at Pre 1 of ISG, Po 1 of KSG, and Pre 2 of PSG. The minimum mean water holding capacity is noted at Pre 2 of Kollakal Thapovanam (16.99 ±19.6), while the maximum is found at Po 2 of Iringole Kavu (52.29 ±2.12). The results of the one-way ANOVA indicate significant differences in average water holding capacity across different seasons in Iringole Kavu and Poyilkavu ($p < 0.05$). In contrast, Kollakal Thapovanam does not show significant differences in average water holding capacity across the various seasons ($p \geq 0.05$) (Annexure 23–25).

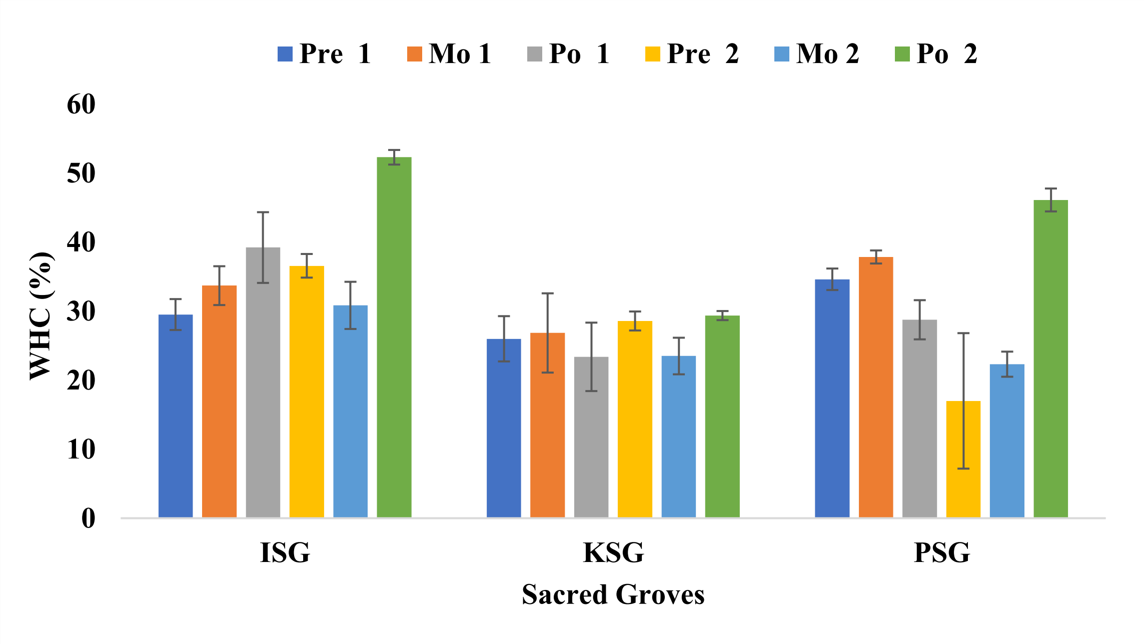

Figure 24. Graph showing the spatial and seasonal variation of water holding capacity in the study area

4.5.7 Available Nitrogen

The available nitrogen levels in the study area range from 182 kg/ha to 432.77 kg/ha. Figure 25 illustrates the spatial and seasonal variations in available nitrogen across different locations. There are significant variations in available nitrogen levels both spatially and seasonally. Poyilkavu and Iringole Kavu have the highest values. Seasonally, the highest nitrogen values are recorded at Pre 2 in ISG and KSG, as well as Mo 2 in PSG. In contrast, the lowest mean available nitrogen values are found at Po 1 of ISG and KSG, and Mo 1 of PSG. The minimum mean available nitrogen is 182 ±14.09 kg/ha, recorded at Po 1 of Kollakal Thapovanam, while the maximum is 432.77 ±202.14 kg/ha at Mo 2 of Poyilkavu. The results of the one-way ANOVA indicate that there are significant differences in the average available nitrogen across different seasons in Iringole Kavu ($p < 0.05$). In contrast, Kollakal Thapovanam and Poyilkavu do not show significant differences in average available nitrogen across the various seasons ($p \geq 0.05$) (Annexure 26–28).

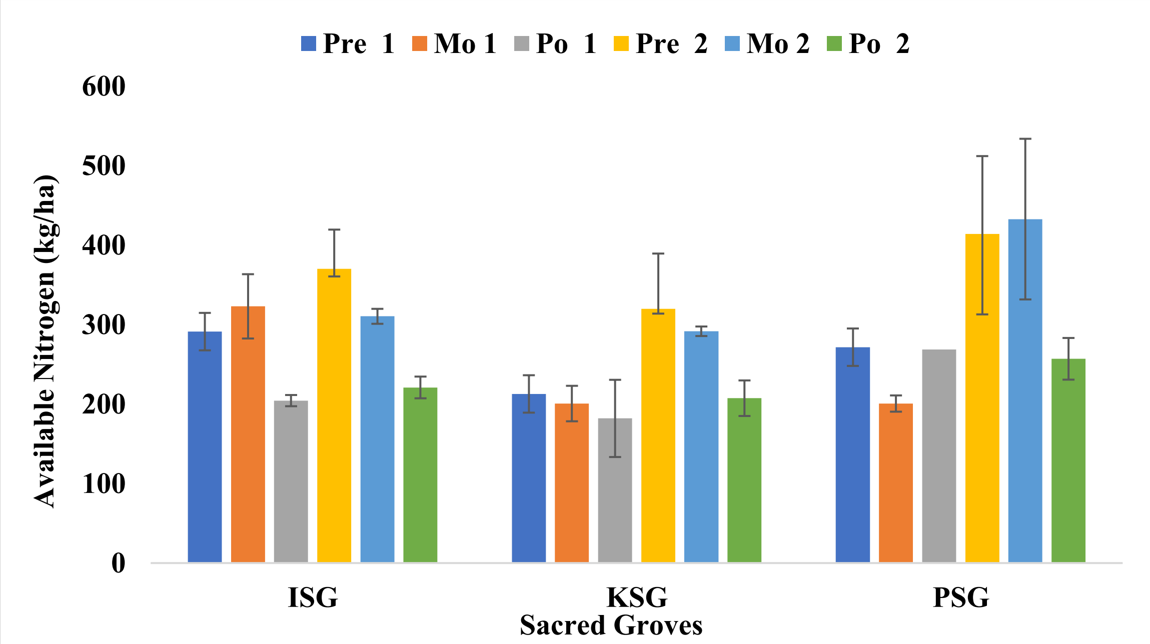

Figure 25. Graph showing the spatial and seasonal variation of available nitrogen in the study area

4.5.8 Available Phosphorus

The available phosphorus levels in the study area range from 13.44 kg/ha to 67.2 kg/ha. Figure 26 illustrates the spatial and seasonal variations in available phosphorus across different locations. Notably, Iringole Kavu has the lowest available phosphorus values across all seasons, whereas Kollakal Thapovanam consistently has the highest available phosphorus levels. Seasonally, the highest available phosphorus values are observed at Pre 1 in ISG and PSG, as well as at Mo 1 in KSG. Conversely, the lowest mean available phosphorus values are recorded at Pre 2 of ISG and Mo 2 of KSG and PSG. Iringole Kavu does not show significant seasonal changes in available phosphorus levels, while the other two sacred groves exhibit considerable seasonal variation in available phosphorus. The minimum mean available phosphorus is recorded at Pre 2 of Iringole Kavu (13.44 ±2.41 kg/ha), while the maximum is found at Mo 1 of Kollakal Thapovanam (67.2 ±24.62 kg/ha). A one-way ANOVA indicates that seasonal variation in available phosphorus is not significant across all sacred groves ($p \geq 0.05$) (Annexure 29–31).

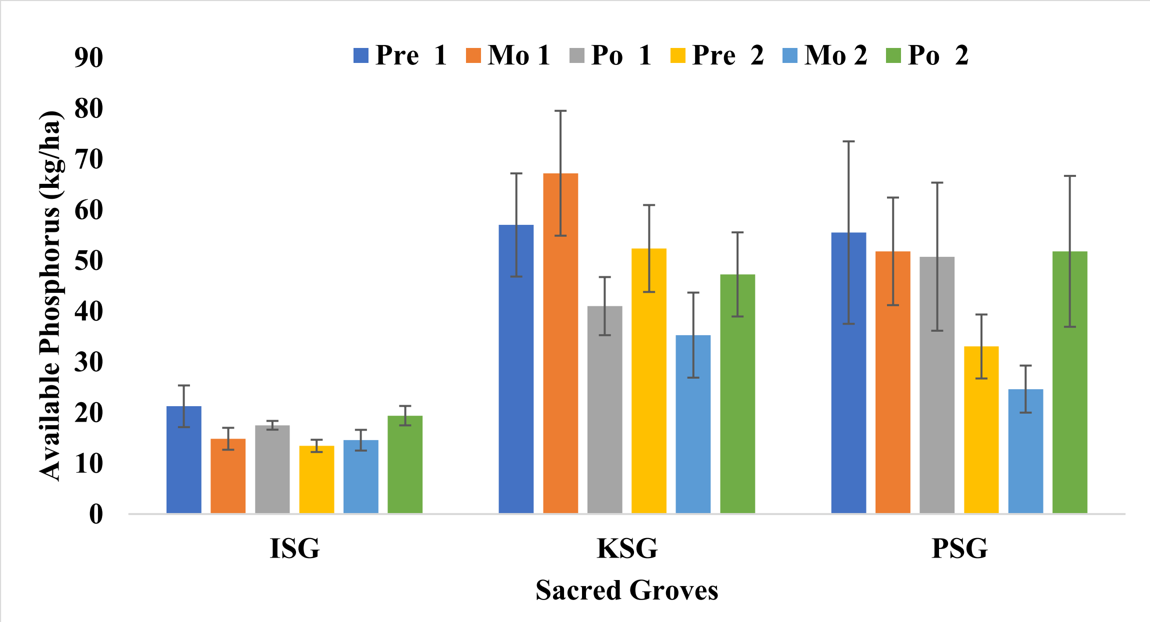

Figure 26. Graph showing the spatial and seasonal variation of available phosphorus in the study area

4.5.9 Available Potassium

The available potassium levels in the study area range from 49.28 kg/ha to 192.55 kg/ha. Figure 27 illustrates the spatial and seasonal variations in available potassium across different locations. These levels exhibit significant seasonal and spatial fluctuations. Iringole Kavu has the highest available potassium level, while Kollakal Thapovanam records the lowest values. Seasonally, the highest available potassium levels are observed at Mo 2 in ISG, Po 1 in KSG, and Pre 2 in PSG. Conversely, the lowest mean available potassium values are found at Po 1 of ISG, Mo 2 of KSG, and PSG. The minimum mean available potassium is recorded at Mo 2 of Kollakal Thapovanam (49.28 ±10.62 kg/ha), whereas the maximum is observed at Mo 2 of Iringole Kavu (192.55 ±74.56 kg/ha). The one-way ANOVA indicates that seasonal variation in available potassium is not significant across all sacred groves ($p \geq 0.05$) (Annexure 32–34).

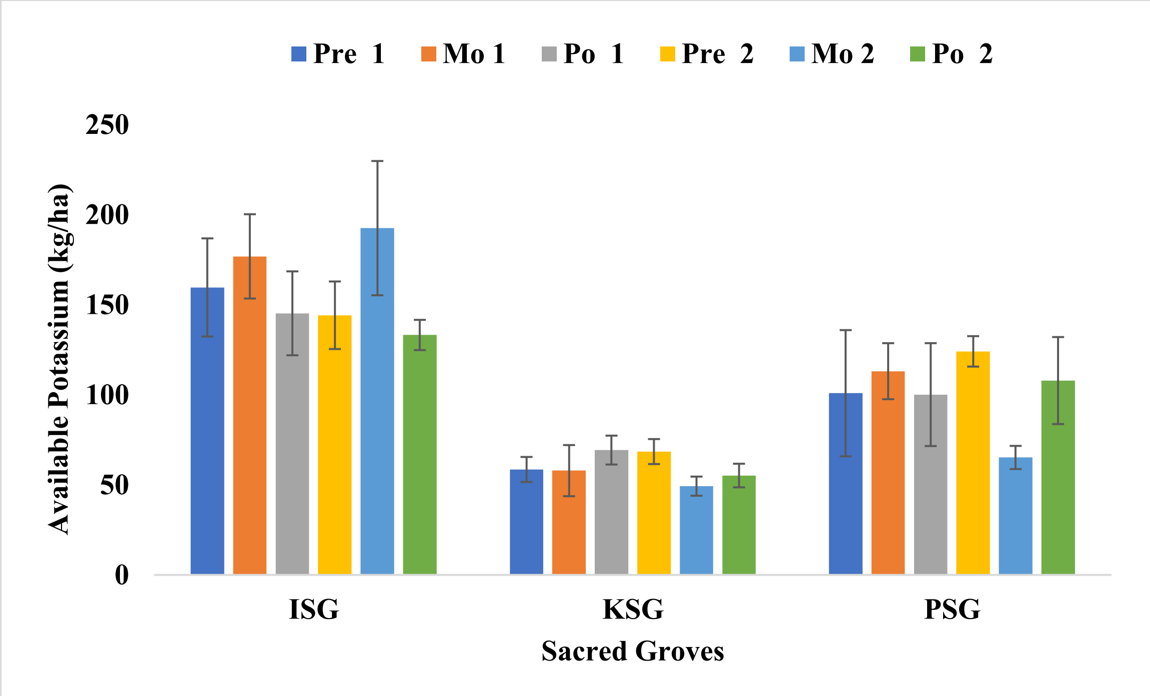

Figure 27. Graph showing the spatial and seasonal variation of available potassium in the study area

4.5.10 Exchangeable Calcium

The exchangeable calcium levels in the study area range from 0.37 Cmol/kg to 6.43 Cmol/kg. Figure 28 illustrates the spatial and seasonal variations in exchangeable calcium across different locations. There are significant spatial and seasonal variations in exchangeable calcium levels. Iringole Kavu has the highest values, while Poyilkavu has the lowest. However, Pre 1 in Poyilkavu has a significantly higher value than the others. Seasonally, the highest exchangeable calcium levels are observed at Po 1 in ISG, Pre 1 in KSG, and PSG. In contrast, the lowest mean exchangeable calcium values occur at Mo 1 in all three sacred groves. The minimum mean exchangeable calcium is recorded at Mo 1 of Kollakal Thapovanam (0.37 ±0.11), whereas the maximum is found at Pre 1 of Poyilkavu (6.43 ±2.59). The one-way ANOVA results indicate no significant differences in average exchangeable calcium across different seasons in Iringole Kavu ($p \geq 0.05$). In contrast, Kollakal Thapovanam and Poyilkavu show significant differences in average exchangeable calcium across the various seasons ($p < 0.05$) (Annexure 35–37).

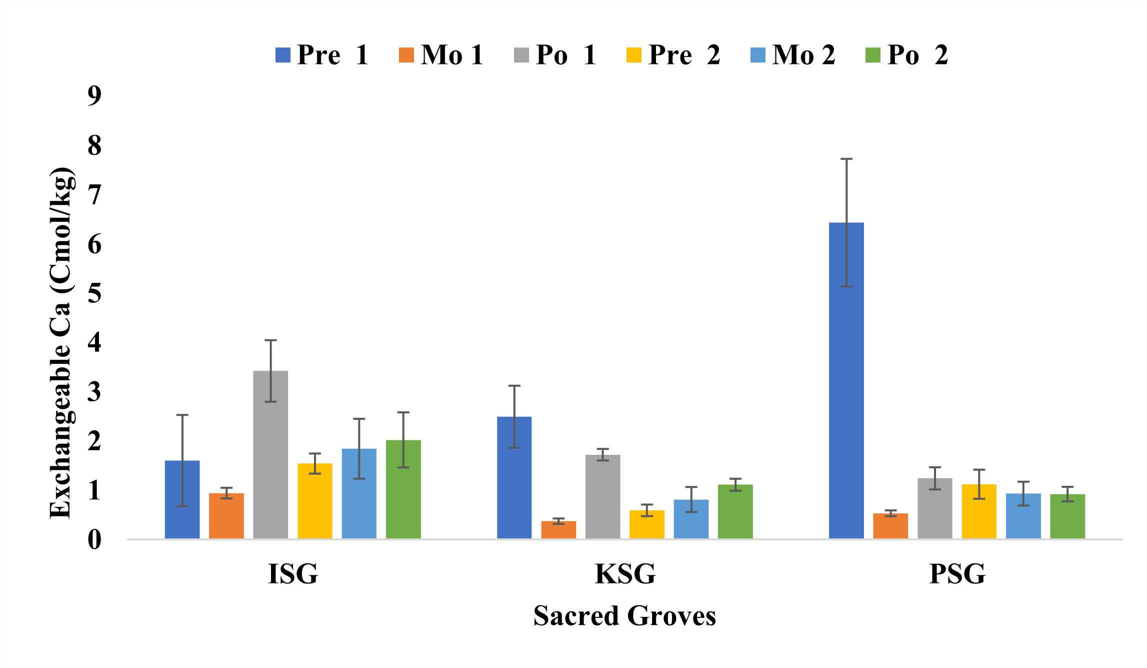

Figure 28. Graph showing the spatial and seasonal variation of exchangeable calcium in the study area

4.5.11 Exchangeable Sodium

The exchangeable sodium levels in the study area range from 0.07 Cmol/kg to 4.54 Cmol/kg. Figure 29 illustrates the spatial and seasonal variations in exchangeable sodium across different locations. Overall, the exchangeable sodium levels are quite low in all the sacred groves, with only the pre-monsoon 1 period showing a significant value. The lowest mean exchangeable sodium is recorded at Pre 2 of Kollakal Thapovanam (0.07 ±0.005), while the highest is found at Pre 1 of Poyilkavu (4.54 ±0.68). The one-way ANOVA shows significant seasonal variation in average exchangeable sodium across all sacred groves ($p < 0.05$) (Annexure 38–40).

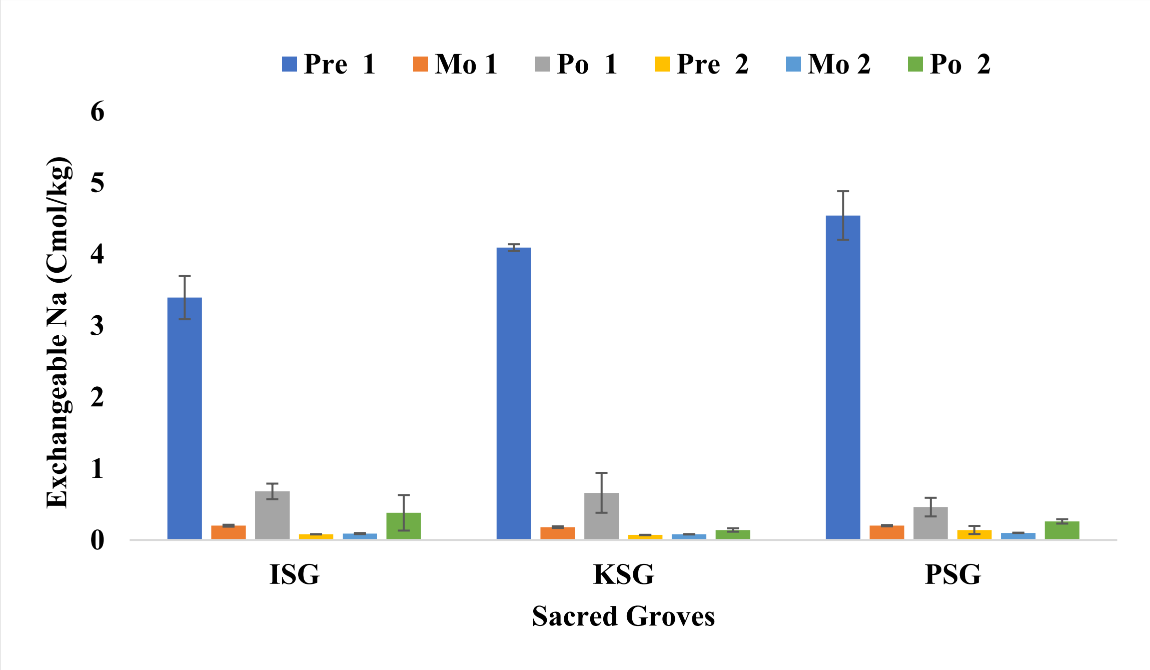

Figure 29. Graph showing the spatial and seasonal variation of exchangeable sodium in the study area

4.5.12 Soil Texture

The soil texture was analysed in each season for every grove, and the results are presented in Table 14. Soil samples were taken from four sites within each grove during each season. The analysis revealed significant variations in soil texture both among the different sites within a grove and between groves in each season.

Table 14. Soil texture analysis

		Site 1	**Site 2**	**Site 3**	**Site 4**
ISG	**Pre 1**	Sandy Loam	Sandy Clay Loam	Gravelly Sandy Clay Loam	Gravelly Loamy Sand
	Pre2	Sandy Clay	Clay Loam	Clay Loam	Gravelly Sandy Clay Loam
	Mo 1	Sandy Loam	Sandy Clay Loam	Gravelly Sandy Clay Loam	Gravelly Loamy Sand
	Mo 2	Clay Loam	Clay Loam	Gravelly Clay	Gravelly Clay Loam
	Po 1	Gravelly Loamy Sand	Gravelly Loamy Sand	Gravelly Loamy Sand	Gravelly Sand
	Po 2	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay
KSG	**Pre 1**	Sand	Sand	Sand	Sand
	Pre2	Sandy Loam	Sandy Loam	Sandy Loam	Loamy Sand

	Mo 1	Sand	Sand	Sand	Sand
	Mo 2	Loamy Sand	Sandy Loam	Loamy Sand	Loamy Sand
	Po 1	Sand	Sand	Sand	Sand
	Po 2	Sandy Clay Loam	Sandy Clay Loam	Sand	Sandy Clay
PSG	**Pre 1**	Loamy Sand	Sand	Sand	Sand
	Pre2	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand
	Mo 1	Loamy Sand	Sand	Sand	Sand
	Mo 2	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
	Po 1	Sandy Loam	Sand	Sand	Loamy Sand
	Po 2	Gravelly Clay	Gravelly Sandy Clay	Clay	Clay

4.6 Correlation Analysis

4.6.1 Canonical Correspondence Analysis

The Canonical Correspondence Analysis (CCA) was conducted to explore the relationship between environmental variables and species distribution in the sacred groves. The analysis included a total of 34 identified genera, which are detailed in Table 15 along with their corresponding abbreviations.

Table 15. Fungal genera and their corresponding abbreviations used in CCA analysis

Genus	**Abbreviation**	**Genus**	**Abbreviation**
Cladosporium	Cla	*Cosmospora*	Cos
Alternaira	Alt	*Fusarium*	Fus
Aspergillus	Asp	*Mariannaea*	Mar
Neosartorya	Neo	*Neocosmospora*	Neo
Paecilomyces	Pae	*Purpureocillium*	Pur
Penicillium	Pen	*Cephalotrichum*	Cep
Talaromyces	Tal	*Microascus*	Mic
Oidiodendron	Oid	*Scedosporium*	Sce
Geotrichum	Geo	*Scopulariopsis*	Sco
Colletotrichum	Col	*Wardomyces*	War
Furcasterigmium	Fur	*Chloridium*	Chl

Plectosphaerella	Ple	*Sirococcus*	Sir
Cordyceps	Cor	*Trichocladium*	Tric
Trichoderma	Tri	*Absidia*	Abs
Acremonium	Acr	*Gongronella*	Gon
Gliomastix	Gli	*Rhizomucor*	Rhi
Sarocladium	Sar	*Mucor*	Muc

In Iringole Kavu, the first two axes account for most of the variation in species distribution, with Axis 1 and Axis 2 capturing the main gradients (Annexures 41 & 42). The tri-plot from the Canonical Correspondence Analysis (CCA) illustrates the correlation between fungi and environmental parameters across different seasons (Figure 30). In this tri-plot, blue dots represent various fungal genera, green lines indicate the environmental variables considered, and black dots denote the different seasons. The length of each arrow corresponds to the significance of the variable.

Together, both axes explain 62.55% of the variation. Specifically, Axis 1 has an eigenvalue of 0.43, accounting for 40.44% of the variation, while Axis 2 has an eigenvalue of 0.23, contributing 22.11% of the variation (Appendix 41). The variables of temperature, available phosphorus, and exchangeable sodium show a positive correlation with Axis 1. Meanwhile, moisture content, available potassium, and exchangeable calcium demonstrate a positive correlation on Axis 2. Additionally, available nitrogen has a positive correlation with both axes.

The variables Pre 1 was positively correlated with Axis 1, while Mo 1, and Mo 2 have positive canonical values on Axis 2. Furthermore, Pre 2 and Po 1 show a positive correlation with both axes. *Neocosmospora* exhibits a strong positive correlation with Axis 1, as its canonical value exceeds 2. *Aspergillus* and *Sarocladium* also display a positive correlation with Axis 1.

On Axis 2, the following genera show positive correlations: *Paeciliomyces, Talaromyces, Oidiodendron, Geotrichum, Colletotrichum, Acremonium, Microascus, Scedosporium, Scopulariopsis, Chloridium, Absidia, Gongronella, and Mucor*. The genera *Alternaria, Penicillium, Plectosphaerella, Cordyceps, Cosmospora, Fusarium, Cephalotrichum,* and *Sirrococcus* are positively correlated with both axes; however, *Alternaria, Plectosphaerella, Cordyceps, Cosmosporium, Cephalotrichum*, and

Sirrococcus exhibit a particularly strong positive correlation with Axis 2, as their canonical values exceed 2. In contrast, *Trichoderma, Purpureocillium*, and *Gliomastix* had niche preferences that extended beyond the analysed parameters.

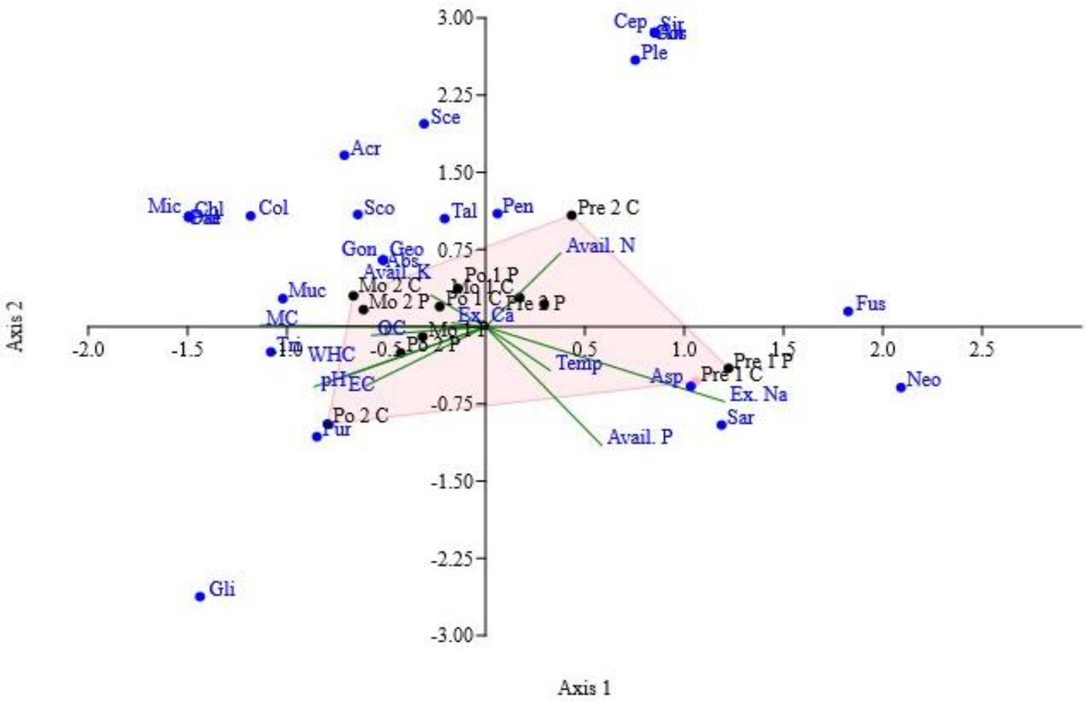

Figure 30. Tri-plot of Canonical Correspondence Analysis across seasons in Iringole Kavu

In Kollakal Thapovanam, the first two axes capture the majority of the variation in species distribution, with Axis 1 and Axis 2 reflecting the main gradients (Annexures 43 & 44). The tri-plot from the Canonical Correspondence Analysis (CCA) illustrates the relationship between fungi and environmental parameters across different seasons (Figure 31). In this tri-plot, blue dots represent various fungal genera, green lines indicate the environmental variables considered, and black dots denote the different seasons. The length of each arrow corresponds to the significance of the variable.

Together, Axes 1 and 2 explain 87.02% of the variation. Specifically, Axis 1 has an eigenvalue of 0.27, accounting for 50.15% of the variation, while Axis 2 has an eigenvalue of 0.20, contributing 36.87% of the variation (Annexure 43). The variables of electrical conductivity, water holding capacity, available phosphorus, and available potassium show a positive correlation with Axis 1, while pH demonstrates a positive correlation with Axis 2. Additionally, temperature, exchangeable calcium, and exchangeable sodium are positively correlated with both axes.

The variables Pre 2, and Mo 1 are positively correlated with Axis 1, whereas Mo 2 exhibits positive canonical values on Axis 2. Furthermore, Pre 1 and Po 1 show a positive correlation with both axes. *Aspergillus* exhibits a positive correlation with Axis 1. *Alternaria, Colletotrichum, Furcasterigmium, Plectosphaerella*, and *Trichocladium* show a strong positive correlation with Axis 2, as their canonical values exceed 2. *Paeciliomyces, Trichoderma, Sarocladium, Fusarium, Purpureocillium,* and *Chloridium* also demonstrate a positive correlation with Axis 2.

The genera *Neocosmospora, Talaromyces, Gliocladium, Microascus*, and *Mucor* are positively correlated with both axes. However, *Neocosmospora, Gliocladium*, and *Microascus* exhibit a particularly strong positive correlation with Axis 2, as their canonical values exceed 2. In contrast, the niche preferences of *Penicillium, Acremonium, Scopulariopsis*, and *Gongronella* may extend beyond the parameters analysed.

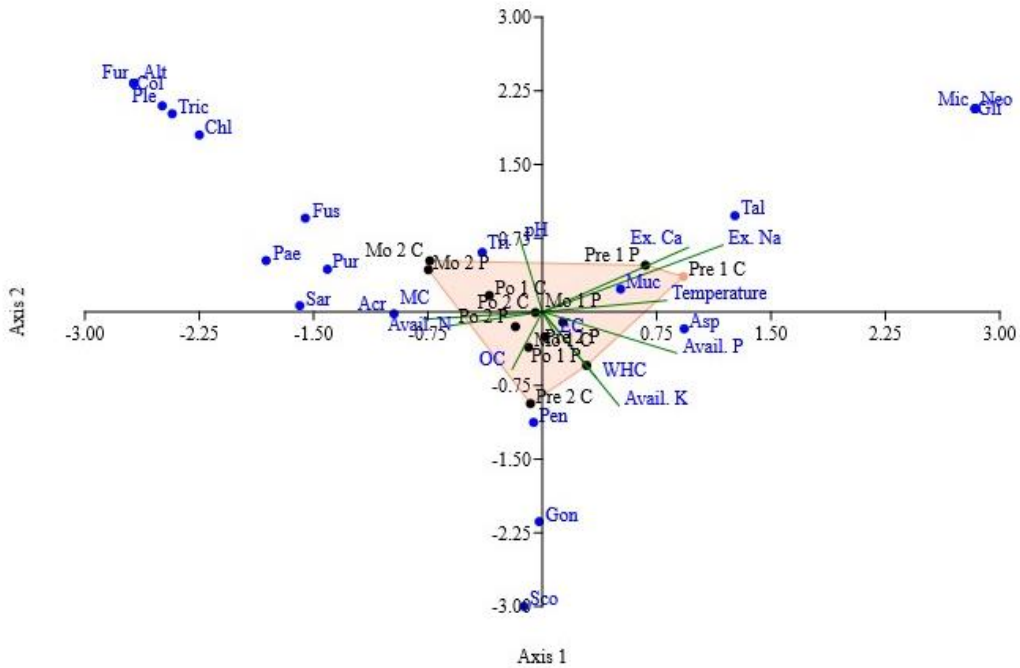

Figure 31. Tri-plot of Canonical Correspondence Analysis across seasons in Kollakal Thapovanam

In Poyilkavu, the first two axes capture the majority of the variation in species distribution, with Axis 1 and Axis 2 representing the primary gradients (Annexures 45 & 46). The tri-plot from the Canonical Correspondence Analysis (CCA) shows the correlation between fungi and environmental parameters across different seasons (Figure 32). In this tri-plot, blue dots represent various fungal genera, green lines indicate the environmental variables considered, and black dots denote the different seasons. The length of each arrow reflects the significance of the corresponding variable.

Together, both axes explain 67.93% of the variation. Specifically, Axis 1 has an eigenvalue of 0.75, accounting for 44.32% of the variation, while Axis 2 has an eigenvalue of 0.40, contributing 23.61% of the variation (Appendix 45). The variables of temperature, pH, exchangeable calcium, and exchangeable sodium show a positive correlation with Axis 1. In contrast, moisture content and electrical conductivity demonstrate a positive correlation with Axis 2. Additionally, organic carbon, water holding capacity, and available phosphorus are positively correlated with both axes.

The variables Pre 1 positively correlate with Axis 1, while Mo 1, and Mo 2, have positive canonical values on Axis 2. Furthermore, Po 1 and Po 2 show a positive correlation with both axes. *Aspergillus* shows a positive correlation with Axis 1, while *Fusarium* exhibits a strong positive correlation with Axis 2, as its canonical value exceeds 2. Other genera that display a positive correlation with Axis 2 include *Penicillium, Talaromyces, Acremonium, Mariannaea, Purpureocillium, Wardomyces, Chloridium, Trichocladium, Gongronella,* and *Rhizomucor.*

Both *Paeciliomyces* and *Scopulariopsis* are positively correlated with both axes; however, they display a particularly strong positive correlation with Axis 2, given that their canonical values exceed 2. In contrast, niches of *Cladosporium, Trichoderma, Sarocladium,* and *Mucor* extend beyond the parameters analysed.

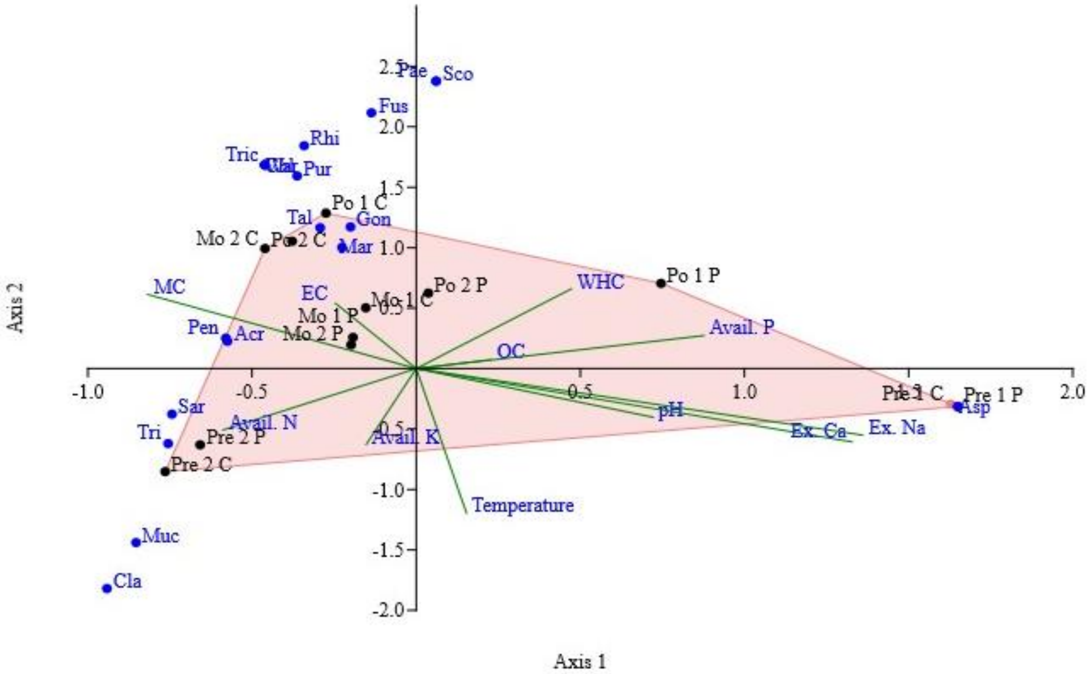

Figure 32. Tri-plot of Canonical Correspondence Analysis across seasons in Poyilkavu

4.6.2 Indicator Species Analysis

Indicator species are biological markers that reflect the biotic or abiotic conditions of an environment (Lawton & Gaston, 2001). The purpose of indicator species analysis is to identify a few characteristic species from a larger group that best represent defined environmental conditions. Indicator species analysis was conducted across sites and seasons. Indicator species are defined as those with a p-value of ≤0.05. Hence, taxa with significant p-values are identified as indicator species for that particular site and season (Annexure 47–50). In the accompanying plot, the indicator species are represented by large circles.

In the spatial analysis (Figure 33), the genera *Aspergillus, Trichoderma*, and *Purpureocillium* were identified as the indicator genera for Iringole Kavu. For Kollakal Thapovanam, the indicator genera include *Penicillium, Mucor, Talaromyces, Acremonium,* and *Trichoderma*, while the indicator genera for Poyilkavu are *Aspergillus, Gongronella, Purpureocillium*, and *Mucor*.

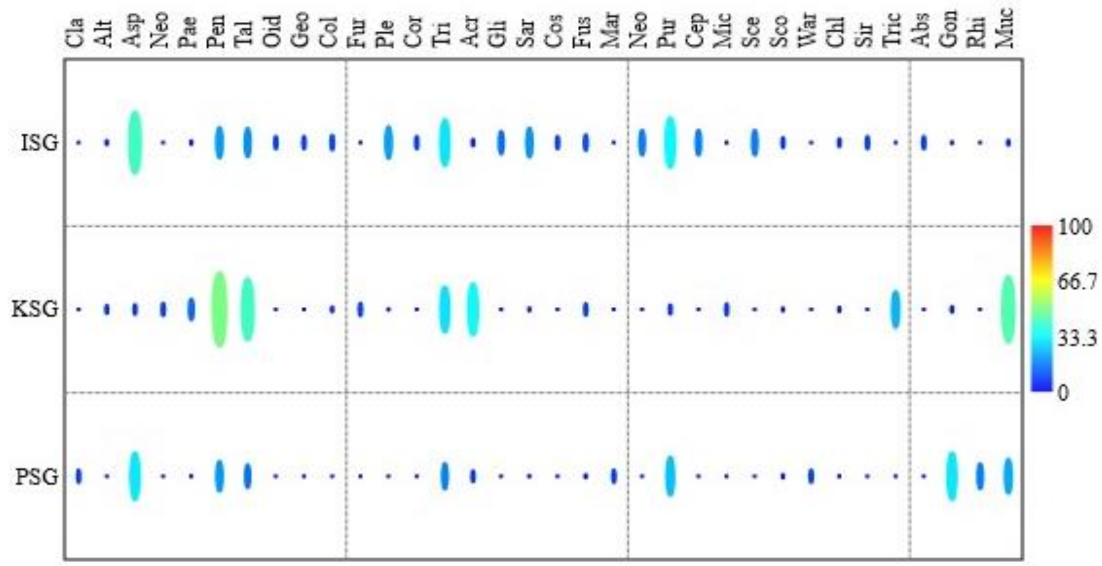

Figure 33. Indicator species analysis plot across sacred groves

In the seasonal analysis for Iringole Kavu (Figure 34), the following indicator genera were identified: *Neocosmospora* and *Sarocladium* for Pre 1; *Alternaria, Cordyceps, Cosmospora*, and *Sirococcus* for Pre 2; *Geotrichum* and *Absidia* for Mo 1; *Paecilomyces, Oidiodendron, Chloridium,* and *Microascus* for Mo 2; *Scopulariopsis* for Po 1; and *Acremonium* for Po 2.

For Kollakal Thapovanam, the seasonal indicator species include *Neocosmospora, Microascus,* and *Gliomastix* for Pre 1; *Scopulariopsis* for Pre 2; *Gongronella* for Mo 1; and *Alternaria, Colletotrichum, Furcasterigmium, Plectosphaerella,* and *Chlordium* for Mo 2. Notably, no indicator species were identified for Po 1 and Po 2 (Figure 35).

In Poyilkavu, the seasonal indicator species included *Aspergillus* for Pre 1; *Cladosporium* for Pre 2; *Mariannae* for Mo 1; *Wardomyces, Trichoderma*, and *Chloridium* for Mo 2; *Paecilomyces* and *Scopulariopsis* for Po 1. No indicator species were found for Po 2 (Figure 36). These findings emphasise that each season and sacred grove possesses unique indicator species.

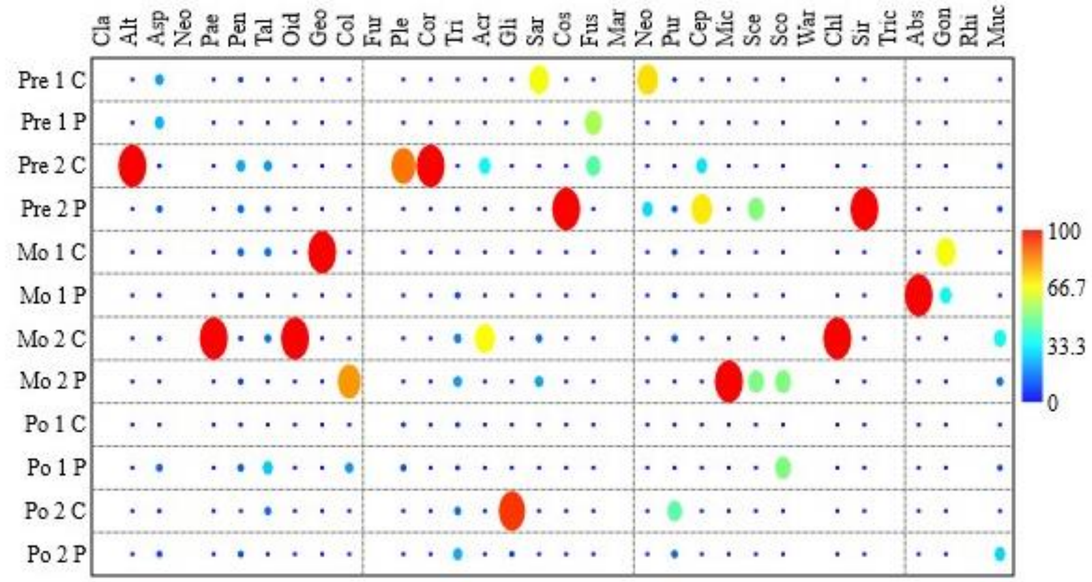

Figure 34. Indicator species analysis plot across seasons in Iringole Kavu

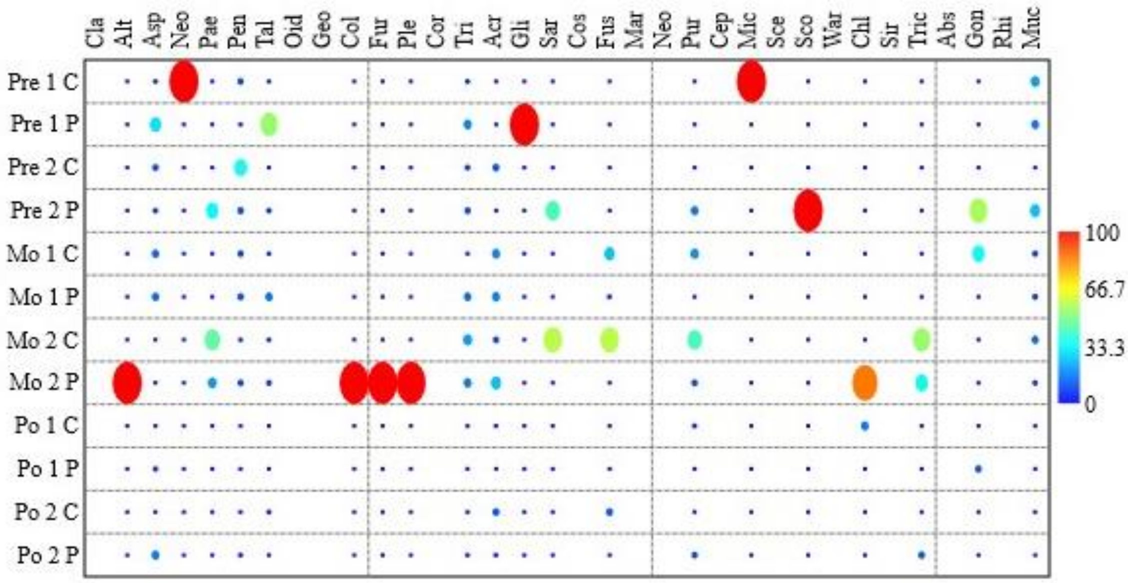

Figure 35. Indicator species analysis plot across seasons in Kollakal Thapovanam

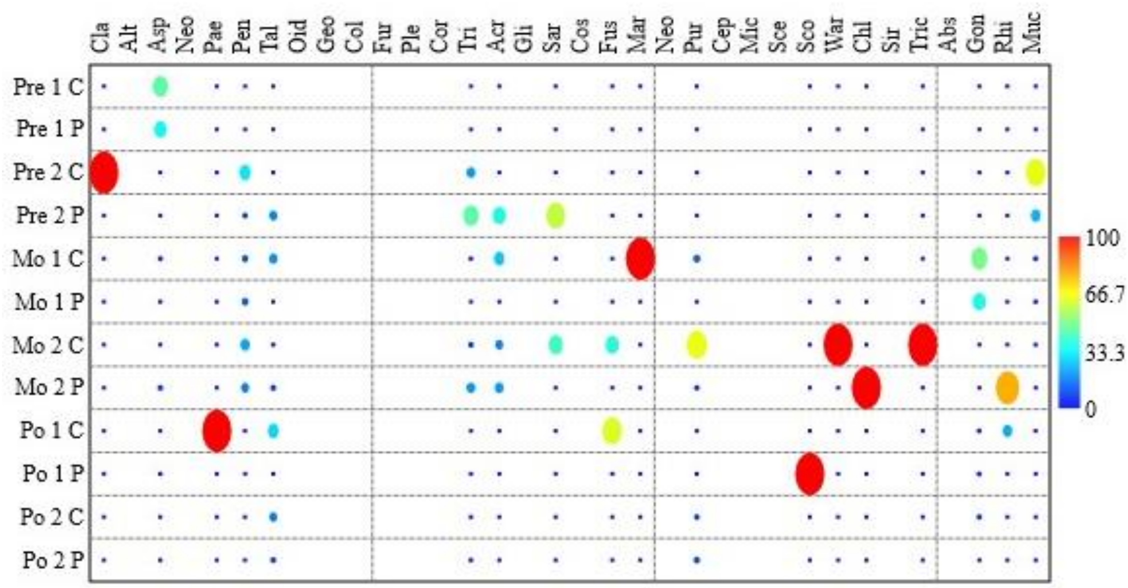

Figure 36. Indicator species analysis plot across seasons in Poyilkavu

4.7 Metagenomics Analysis

4.7.1 Sequence Data Analysis

The metagenomics sequences of three samples from three sacred groves were deposited at the Sequence Read Archive (SRA of National Centre for Biotechnology Information, NCBI) with Bio project number (PRJNA881851) and the Bio-sample accession numbers SAMN30917060, SAMN30917061, SAMN30917062 (Table 16).

Table 16: Minimal information about metagenomics sequence (MIMS) for the NGS sequence data submitted to SRA database of GenBank in NCBI for the soil of sacred groves

Structured comment name	Iringole Kavu	Kollakal Thapovanam	Poyilkavu
Submitted to	Sequence Read Archive (SRA), Accession number: SAMN30917060	Sequence Read Archive (SRA), Accession number: SAMN30917061	Sequence Read Archive (SRA), Accession number: SAMN30917062
Sample name	ISG (S1)	KSG (S2)	PSG (S3)
Project name	Metagenomics study of soil fungi from Iringole sacred	Metagenomics study of soil fungi from Kollakal	Metagenomics study of soil fungi from Poyilkavu sacred

	grove	Thapovanam sacred grove	grove
Investigation type	Diversity of soil fungi from Iringole Sacred grove	Diversity of soil fungi from Kollakal Thapovanam Sacred grove	Diversity of soil fungi from Poyilkavu Sacred grove
Environment type	Iringole Sacred grove, Ernakulam, Kerala	Kollakal Thapovanam Sacred grove, Alappuzha, Kerala	Poyilkavu Sacred grove, Kozhikode, Kerala
Geographical location name	India	India	India
Collection date	10-04-2022	17-04-2022	07-05-2022
Latitude and Longitude	10°06′32.71″ N 76°30′01.44″ E	9°11′05.19″ N 76°27′41.30″ E	11°24′31.49″ N 75°42′49.37″ E
Elevation	37m	2m	5m
Material	Soil	Soil	Soil
Depth	0 to 10cm	0 to 10cm	0 to 10cm
Organism	Soil fungi	Soil fungi	Soil fungi
Biome	Sacred grove	Sacred grove	Sacred grove
Material	Soil	Soil	Soil
Sequencing Method	Illumina MiSeq	Illumina MiSeq	Illumina MiSeq
Library Strategy	ITS 124 Amplicon	ITS 124 Amplicon	ITS 124 Amplicon

A total of 110426, 283208 and 192866 reads were obtained from the soil samples taken from Iringole Kavu, Kollakal Thapovanam and Poyilkavu, respectively. Among these, 55213 reads were paired-end reads in Iringole Kavu, while 141604 and 96433 reads were paired-end reads in Kollakal Thapovanam and Poyilkavu, respectively. These paired-end reads are in the format of FASTq files with file names S1_R1.fastq.gz, S2_R1.fastq.gz, and S3_R1.fastq.gz, and are 250 bp in length. The average GC% for Iringole Kavu, Kollakal Thapovanam and Poyilkavu were 58.55%, 58.56%, and 58.68%, respectively (Table 17) (Annexure 51–68).

Table 17. Raw read information

	Total reads	Total paired reads	Raw read length	Average GC%
ISG	1,10,426	55,213	250bp	58.55%
KSG	2,83,208	1,41,604	250bp	58.56%
PSG	1,92,866	96,433	250bp	58.68%

All fastq files were imported into the QIIME2 software for further analysis. The "Dada2" method was utilised to denoise the sequences and to better discriminate between true sequence diversity and sequencing errors. The summary of the denoising statistics is given in Table 18.

Table 18: Summary of denoising statistics

	Input	Filtered	Input passed filter %	Denoised	Merged	Input merged %	Non-chimeric	Input non-chimeric %
ISG	55,213	45,126	81.73	44,365	30,854	55.88	30,854	55.88
KSG	1,41,604	1,18,948	84	1,17,804	78,365	55.34	78,323	55.31
PSG	96,433	85,634	88.8	84,740	55,640	57.7	55,640	57.7

After the paired-end reads were denoised, we obtained a total of 30854 reads for Iringole Kavu, 78323 reads for Kollakal Thapovanam, and 55640 reads for Poyilkavu. These reads were then clustered into Operational Taxonomic Units (OTUs) using a classifier model trained on UNITE version 8. Once the OTUs were identified, they were classified into Phylum, Class, Order, Family, Genus, and Species for each sample (Figure 37).

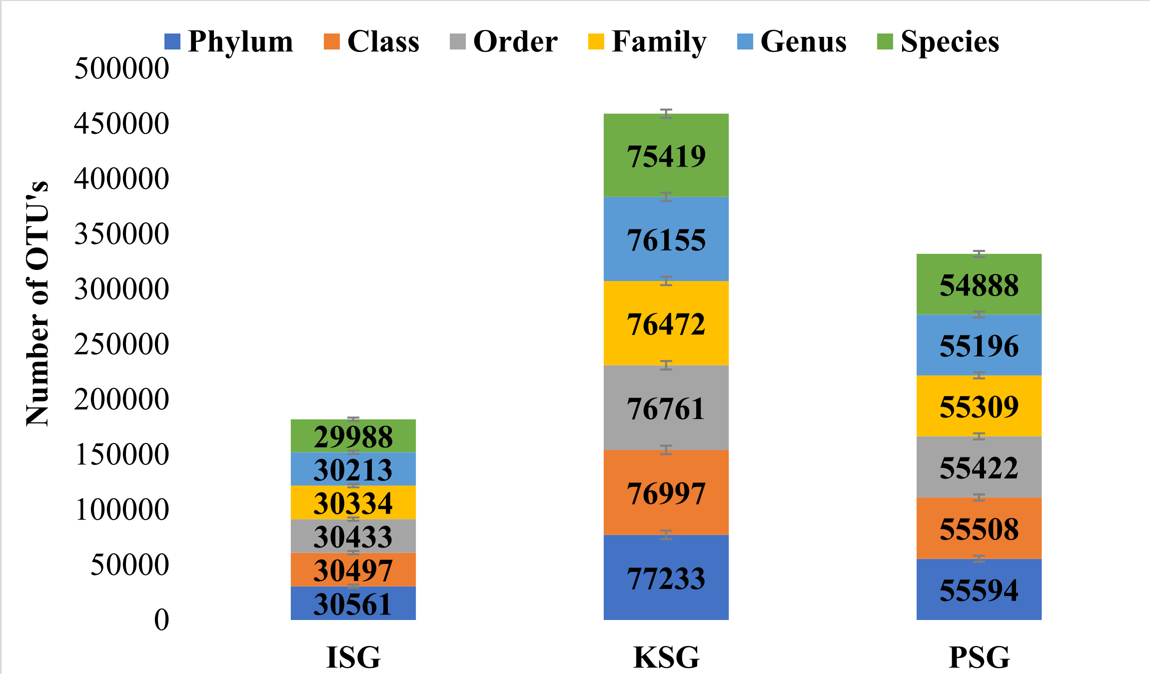

Figure 37. Graph showing the number of OTUs of each sample at each classification level

4.7.2 Quantitative Analysis

The taxonomic hierarchy of OTU was analysed using a Krona plot. (Figure 38, 39, 40). The categories Kingdom, Phylum, Order, Class, Family and Genus were selected. Less abundant and unresolved taxa, grouped as unidentified, were listed outside the chart with their relative abundance (Annexure 69–74). The Krona plot revealed that Ascomycota was the most abundant phylum in all three sacred groves, accounting for about 97%, 98% and 96% of the total OTU of Iringole Kavu, Kollakal Thapovanam, and Poyilkavu, respectively. Other phyla observed were Mortierellomycota, Basidiomycota, Chytridiomycota, and Rozellomycota.

In Iringole Kavu, Ascomycota was the most abundant phyla, followed by Mortierellomycota (1.7%), Basidiomycota (0.6%), Chytridiomycota (0.2%), and Rozellomycota. These phyla were subdivided into 12 classes, 22 orders, 42 families, 53 genera, and 56 species. In Kollakal Thapovanam, Ascomycota is followed by Basidiomycota (2%), Mortierellomycota (0.4%), Rozellomycota (0.3%) and Chytridiomycota (0.01%). These phyla were subdivided into 17 classes, 33 orders, 60 families, 81 genera, and 88 species. In Poyilkavu, Ascomycota was the dominant phylum followed by Basidiomycota (3%), Mortierellomycota (0.5%), Rozellomycota

(0.04%) and Chytridiomycota (0.02%). These phyla were subdivided into 15 classes, 29 orders, 50 families, 69 genera, and 67 species. Taxonomically unresolved sequences were grouped under unidentified Class, Family, Order, Genera, and Species (Figure 41).

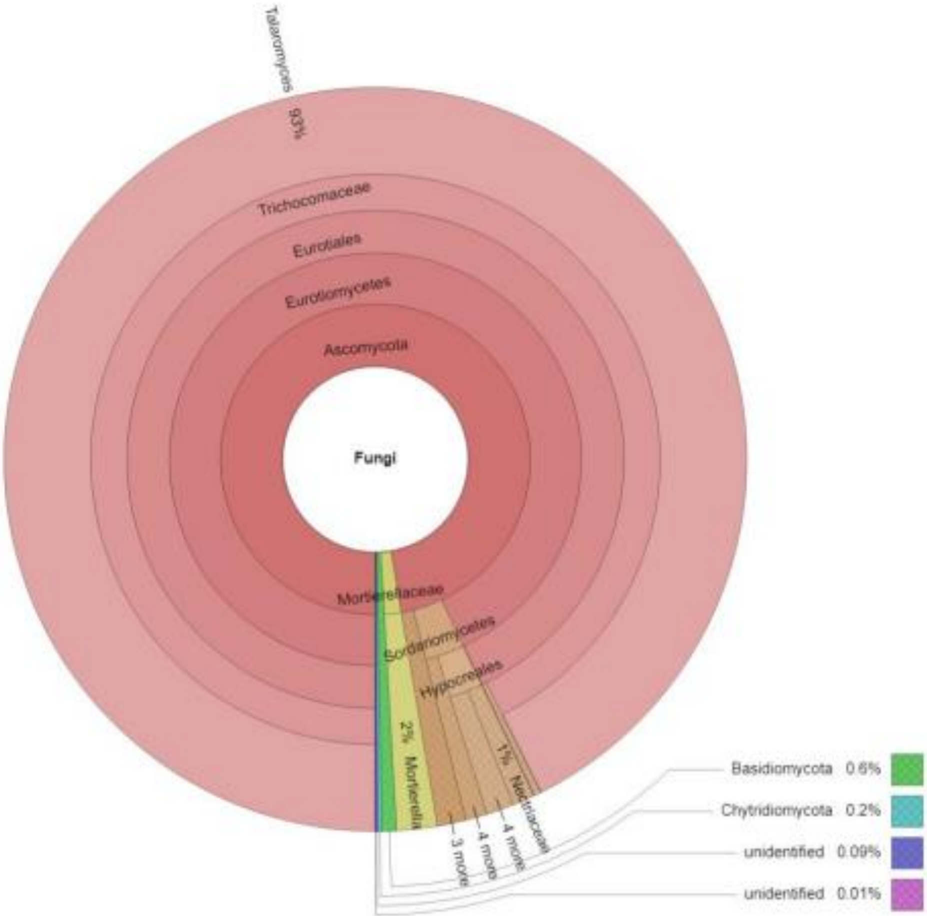

Figure 38. Krona plot showing the taxonomic composition of soil sample of Iringole Kavu

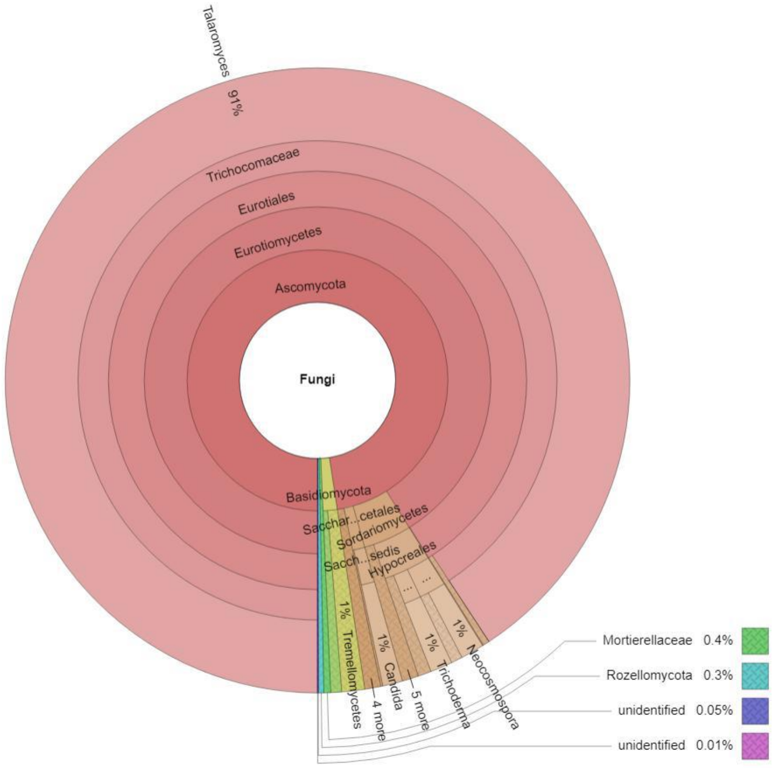

Figure 39. Krona plot showing the taxonomic composition of soil sample of Kollakal Thapovanam

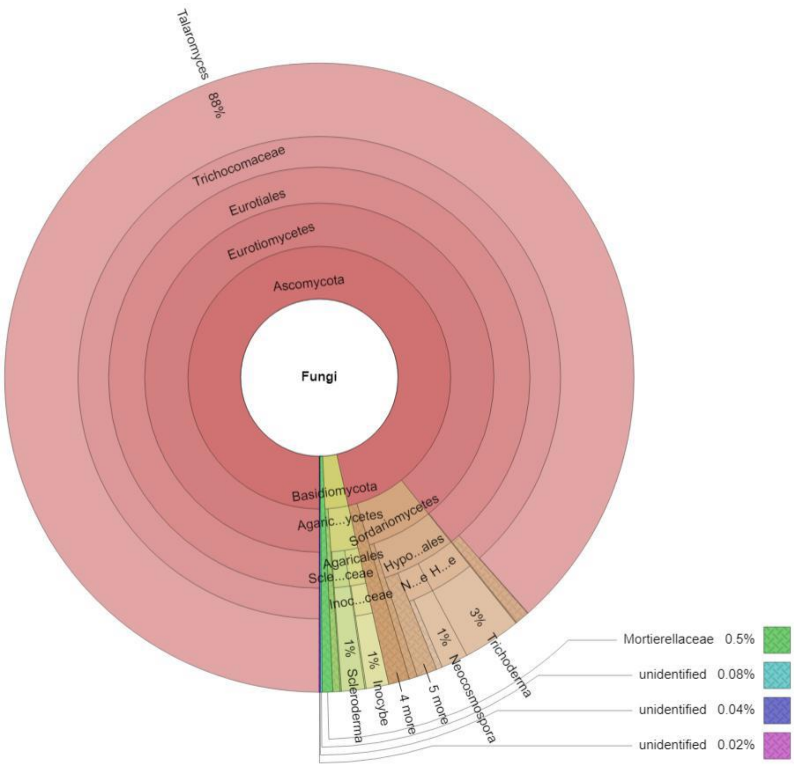

Figure 40. Krona plot showing the taxonomic composition of soil sample of Poyilkavu

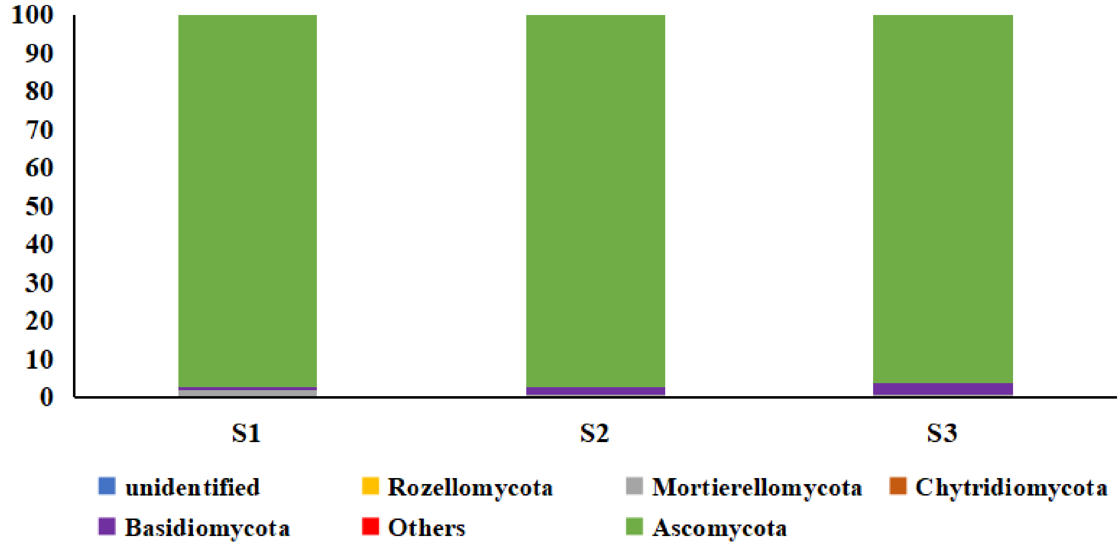

Figure 41. Graph showing the taxonomic assignment at the phylum level

4.7.3 Taxonomy Analysis

The checklist of identified taxa is presented in Table 19. It includes only those taxa that have been identified to at least the genus level. A total of 441 fungal taxa were obtained, with 205 specifically identified at the genus level and included in the checklist. Meanwhile, 236 taxa remain unidentified. Some of these unidentified taxa have been classified to the family or class level, while others are recognized only as fungi, without further details available. The composition and abundance distributions for each sample were analysed at six levels of classification.

In the checklist, the fungal taxa were arranged in the following order.

Phylum: Ascomycota

Basidiomycota

Chytridiomycota

Mortierellomycota

Rozellomycota

Table 19. Checklist of the taxa identified using metagenomics analysis

Phylum	Class	Order	Family	Species
Ascomycota	Archaeorhizomycetes	Archaeorhizomycetales	Archaeorhizomycetaceae	*Archaeorhizomyces* sp. 1
	Dothideomycetes	Botryosphaeriales	Botryosphaeriaceae	*Lasiodiplodia margaritacea*
		Capnodiales	Cladosporiaceae	*Cladosporium sphaerospermum*
				Cladosporium tenuissimum
				Cladosporium velox
				Cladosporium sp. 1
				Toxicocladosporium irritans
			Mycosphaerellaceae	*Mycosphaerella tassiana*
				Ramularia eucalypti
				Septoria cretae
		Dothideales	Incertae sedis	*Selenophoma mahoniae*
		Pleosporales	Amorosiaceae	*Angustimassarina acerina*
			Coniothyriaceae	*Coniothyrium multiporum*
			Cucurbitariaceae	*Pyrenochaetopsis leptospora*
			Incertae sedis	*Cryptocoryneum brevicondensatum*
				Pseudorobillarda sp. 1
			Morosphaeriaceae	*Acrocalymma* sp. 1
			Phaeosphaeriaceae	*Phaeosphaeria oryzae*
				Setophoma chromolaenae
			Pleosporaceae	*Alternaria angustiovoidea*

				Bipolaris urochloae
			Sporormiaceae	*Preussia terricola*
				Westerdykella nigra
				Westerdykella sp. 1
			Tetraplosphaeriaceae	*Tetraploa* sp. 1
			Thyridariaceae	*Roussoella solani*
				Roussoella sp. 1
				Roussoella sp. 2
				Roussoella sp. 3
	Eurotiomycetes	Chaetothyriales	Herpotrichiellaceae	*Cladophialophora* sp. 1
				Phialophora sp. 1
				Phialophora sp. 2
		Eurotiales	Aspergillaceae	*Aspergillus diversus*
				Aspergillus heterocaryoticus
				Aspergillus penicillioides
				Aspergillus ruber
				Aspergillus subversicolor
				Aspergillus sydowii
				Aspergillus sp. 1
				Aspergillus sp. 2
				Aspergillus sp. 3
				Penicillium arianeae

		Penicillium citrinum
		Penicillium longicatenatum
		Penicillium malachiteum
		Penicillium sp.1
		Penicillium sp. 2
		Penicillium sp. 3
	Trichocomaceae	*Talaromyces albobiverticillius*
		Talaromyces neofusisporus
		Talaromyces tzapotlensis
		Talaromyces sp. 1
		Talaromyces sp. 2
		Talaromyces sp. 3
		Talaromyces sp. 4
		Talaromyces sp. 5
		Talaromyces sp. 6
		Talaromyces sp. 7
		Talaromyces sp. 8
		Talaromyces sp. 9
		Talaromyces sp. 10
		Talaromyces sp. 11
		Talaromyces sp. 12
		Talaromyces sp. 13

				Thermomyces sp. 1
				Xerochrysium dermatitidis
		Onygenales	Onygenaceae	*Arachnotheca glomerata*
	Leotiomycetes	Helotiales	Leotiaceae	*Gorgomyces hungaricus*
	Orbiliomycetes	Orbiliales	Orbiliaceae	*Arthrobotrys* sp. 1
	Pezizomycetes	Pezizales	Ascobolaceae	*Ascobolus foliicola*
			Ascodesmidaceae	*Cephaliophora tropica*
			Incertae sedis	*Trichobolus zukalii*
	Saccharomycetes	Saccharomycetales	Debaryomycetaceae	*Kurtzmaniella* sp. 1
			Incertae sedis	*Candida albicans*
				Candida ethanolica
				Candida hyderabadensis
				Candida pseudojiufengensis
				Candida tropicalis
			Lipomycetaceae	*Lipomycs yarrowii*
			Phaffomycetaceae	*Cyberlindnera sargentensis*
			Pichiaceae	*Dekkera bruxellensis*
			Saccharomycetaceae	*Kazachstania africana*
	Sordariomycetes	Chaetosphaeriales	Chaetosphaeriaceae	*Chloridium aseptatum*
		Glomerellales	Glomerellaceae	*Colletotrichum xanthorrhoeae*
				Colletotrichum sp. 1
			Plectosphaerellaceae	*Gibellulopsis* sp. 1

			Plectosphaerella oratosquillae
	Hypocreales	Bionectriaceae	*Bionectria rossmaniae*
			Clonostachys chlorina
			Clonostachys compactiuscula
			Clonostachys sp. 1
			Stilbocrea sp. 1
		Clavicipitaceae	*Metacordyceps chlamydosporia*
			Metarhizium anisopliae
		Cordycipitaceae	*Beauveria felina*
		Hypocreaceae	*Trichoderma hunanense*
			Trichoderma lixii
			Trichoderma turrialbense
			Trichoderma virilente
			Trichoderma sp. 1
			Trichoderma sp. 2
			Trichoderma sp. 3
		Incertae sedis	*Acremonium alternatum*
			Acremonium hennebertii
			Acremonium persicinum
			Acremonium pinkertoniae
			Acremonium polychromum
			Acremonium tubakii

			Emericellopsis sp. 1
			Emericellopsis sp. 2
			Leucosphaerina arxii
			Sarocladium oryzae
		Nectriaceae	*Campylocarpon* sp. 1
			Fusarium delphinoides
			Fusarium solani
			Fusarium sp. 1
			Fusarium sp. 2
			Fusarium sp. 3
			Gibberella sp. 1
			Gliocephalotrichum humicola
			Ilyonectria macrodidyma
			Mariannaea camptospora
			Mariannaea punicea
			Neocosmospora falciformis
			Penicillifer diparietisporus
			Stephanonectria keithii
		Ophiocordycipitaceae	*Tolypocladium* sp. 1
			Tolypocladium sp. 2
		Stachybotryaceae	*Memnoniella longistipitata*
	Microascales	Microascaceae	*Acaulium* sp. 1

			Kernia geniculotricha
			Petriellopsis africana
			Pseudallescheria angusta
	Sordariales	Chaetomiaceae	*Amesia atrobrunnea*
			Botryotrichum atrogriseum
			Chaetomium longicolleum
			Humicola sardiniae
			Zopfiella sp. 1
		Incertae sedis	*Cordana bisbyi*
	Trichosphaeriales	Trichosphaeriaceae	*Nigrospora* sp. 1
			Nigrospora sp. 2
	Xylariales	Bartaliniaceae	*Bartalinia pondoensis*
		Diatrypaceae	*Peroneutypa scoparia*
		Incertae sedis	*Hansfordia pulvinata*
			Hansfordia sp. 1
			Phialemoniopsis pluriloculosa
		Xylariaceae	*Ascotricha guamensis*
			Hypoxylon hypomiltum
			Nemania primolutea
			Xylaria cubensis
			Xylaria sp. 1
	Chaetosphaeriales	Chaetosphaeriaceae	*Chloridium aseptatum*

		Glomerellales	Glomerellaceae	*Colletotrichum xanthorrhoeae*
				Colletotrichum sp. 1
Basidiomycota	Agaricomycetes	Agaricales	Amanitaceae	*Amanita inopinata*
			Hygrophoraceae	*Hygrocybe glutinipes*
			Inocybaceae	*Inocybe gregaria*
			Psathyrellaceae	*Coprinellus domesticus*
			Physalacriaceae	*Flammulina velutipes* var. *himalayana*
		Boletales	Sclerodermataceae	*Scleroderma sinnamariense*
		Cantharellales	Ceratobasidiaceae	*Thanatephorus cucumeris*
		Polyporales	Polyporaceae	*Funalia floccosa*
			Ganodermataceae	*Ganoderma gibbosum*
				Ganoderma sp. 1
			Polyporaceae	*Hexagonia tenuis*
			Meruliaceae	*Phlebia* sp. 1
		Sebacinales	Sebacinaceae	*Sebacina* sp. 1
		Trechisporales	Hydnodontaceae	*Trechispora* sp. 1
	Agaricostilbomycetes	Agaricostilbales	Agaricostilbaceae	*Sterigmatomyces halophilus*
			Kondoaceae	*Kondoa sorbi*
	Cystobasidiomycetes	Cystobasidiales	Cystobasidiaceae	*Cystobasidium fimetarium*
		Erythrobasidiales	Erythrobasidiaceae	*Erythrobasidium hasegawianum*
	Exobasidiomycetes	Doassansiales	Doassansiaceae	*Heterodoassansia hygrophilae*
	Geminibasidiomycetes	Geminibasidiales	Geminibasidiaceae	*Geminibasidium* sp. 1

				Geminibasidium sp. 2
	Microbotryomycetes	Leucosporidiales	Leucosporidiaceae	*Leucosporidium scottii*
		Sporidiobolales	Sporidiobolaceae	*Rhodotorula sphaerocarpa*
				Rhodotorula toruloides
	Tremellomycetes	Filobasidiales	Filobasidiaceae	*Filobasidium oeirense*
				Naganishia diffluens
		Tremellales	Bulleribasidiaceae	*Vishniacozyma carnescens*
				Vishniacozyma taibaiensis
				Vishniacozyma victoriae
			Rhynchogastremataceae	*Papiliotrema mangalensis*
			Tremellaceae	*Cryptococcus uniguttulatus*
			Trimorphomycetaceae	*Saitozyma flava*
				Saitozyma podzolica
		Trichosporonales	Trichosporonaceae	*Apiotrichum dehoogii*
				Apiotrichum scarabaeorum
				Trichosporon asahii
				Trichosporon ovoides
	Ustilaginomycetes	Ustilaginales	Ustilaginaceae	*Moesziomyces antarcticus*
	Wallemiomycetes	Wallemiales	Wallemiaceae	*Wallemia* sp. 1
Chytridiomycota	Rhizophydiomycetes	Rhizophydiales	Terramycetaceae	*Terramyces* sp. 1
				Terramyces sp. 2
Mortierellomycota	Mortierellomycetes	Mortierellales	Mortierellaceae	*Mortierella alpina*

				Mortierella amoeboidea
				Mortierella capitata
				Mortierella epigama
				Mortierella formicae
				Mortierella minutissima
				Mortierella polygonia
				Mortierella sp. 1
				Mortierella sp. 2
Rozellomycota	unidentified	unidentified	unidentified	Unidentified

On the class level (Figure 42), Eurotiomycetes belonging to phylum Ascomycota was the most prominent class in all the three sacred groves, accounting for about 93% of the OTU in Iringole Kavu, 91% of the OTU in Kollakal Thapovanam and 89% of the OTU in Poyilkavu. Sordariomycetes of Ascomycota was the second most abundant class. Mortierellomycetes (2%) of the phylum Mortierellomycota, Saccharomycetes (0.6%) and Dothidiomycetes (0.5%) of the phylum Ascomycota were the other dominant classes found in Iringole Kavu. In Kollakal Thapovanam, Saccharomycetes (1%) of Ascomycota, Tremellomycetes (1%) of Basidiomycota and Dothidiomycetes (0.7%) of the phylum Ascomycota were the other dominating classes. In Poyilkavu, Agaricomycetes (2%) of Basidiomycota, Dothidiomycetes (0.6%) of Ascomycota and Mortierellomycetes (0.5%) of Mortierellomycota were the dominating classes.

Out of the 20 classes identified, Kollakal Thapovanam has the highest number of classes (17). Class Rhizophydiomycetes were seen only in Iringole Kavu, Archaeorhizomycetes were seen only in Poyilkavu, whereas Ustilaginomycetes, Exobasidiomycetes, Rozellomycotina cls Incertae sedis and Orbilliomycetes were seen only in Kollakal Thapovanam. Class Geminibasidiomycetes was seen only in Iringole Kavu and Poyilkavu. Leotiomycetes, Microbotryomycetes and Agaricostilbomycetes were seen only in Kollakal Thapovanam and Poyilkavu.

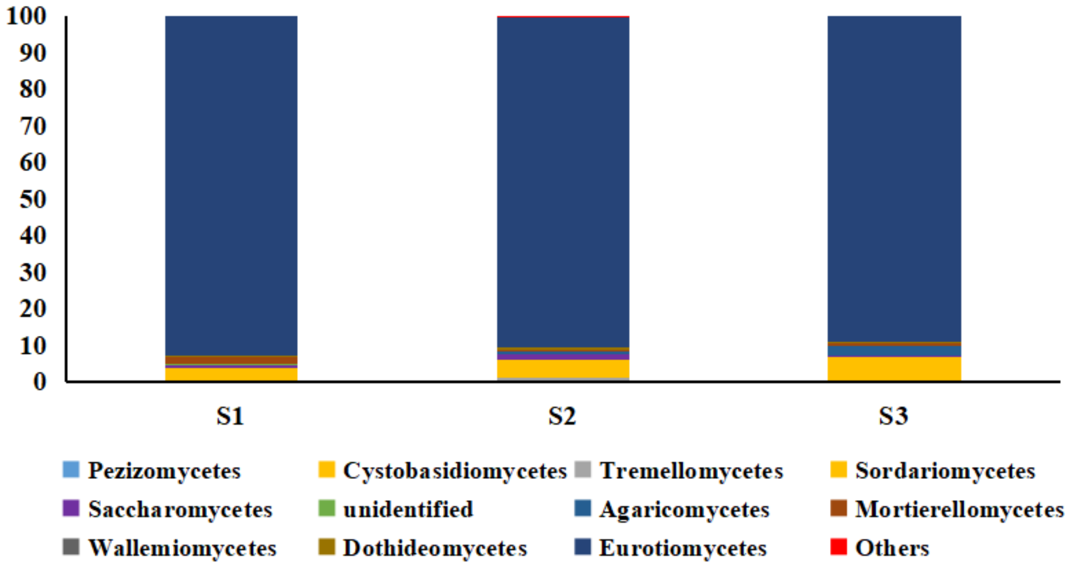

Figure 42. Graph showing the taxonomic assignment at the class level

Based on the number of representative OTU (Figure 43), Eurotiales (Class Eurotiomycetes) was the most abundant order in all the three sacred groves with 28228 OTU in Iringole Kavu, 69687 OTU in Kollakal Thapovanam and 48907 OTU in Poyilkavu followed by Hypocreales. Mortierellales, Saccharomycetales and Sordariales are the other dominating orders found in Iringole Kavu whereas Saccharomycetales, Tremellales and Capnodiales are the other dominating orders in Kollakal Thapovanam. In Poyilkavu, Agaricales, Boletales and Mortierellales became the other dominating orders.

A total of 40 orders were identified, and Kollakal Thapovanam had the highest number of orders with 33. Seven orders, including Leucosporidiales, Ustilaginales, Doassansiales, Erythrobasidiales, Botryosphaeriales, Dothideales, and Orbiliales were seen only in Kollakal Thapovanam. Meanwhile, Rhizophydiales and Oxygenales were found only in Iringole Kavu. Cantharellales, Trichosphaeriales, Archaeorhizomycetales and Trechisporales were found only in Poyilkavu.

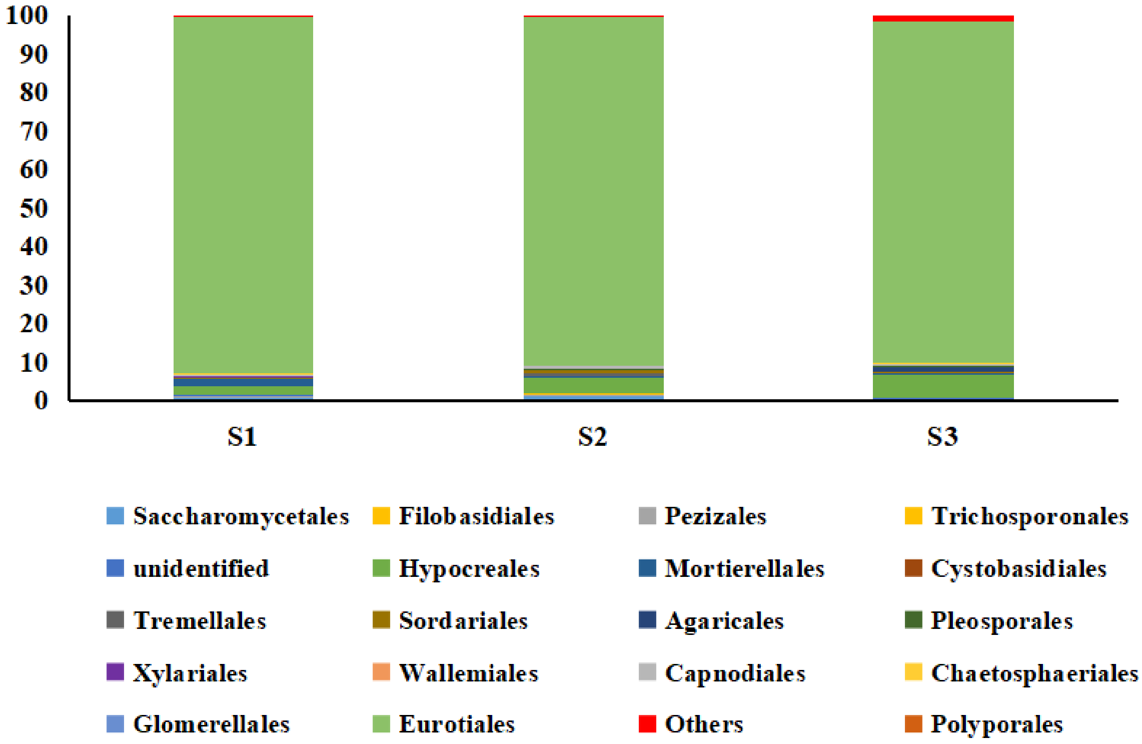

Figure 43. Graph showing the taxonomic assignment at the order level

Family Trichomaceae was the most abundant family in all three sacred groves, with 28145 OTU in Iringole Kavu, 69432 OTU in Kollakal Thapovanam and 48509 OTU in Poyilkavu. Mortierellaceae, Necteriaceae, and Incertae sedis of the Pezizales family were the other dominating families in Iringole Kavu. Meanwhile, Nectericaceae and Hypocreaceae became the other dominating families in Kollakal Thapovanam and Poyilkavu (Figure 44).

Out of 83 families identified, Kollakal Thapovanam had the highest number of families (60). 26 families were common to all the sacred groves. 21 families were seen only in Kollakal Thapovanam, 11 families were found only in Poyilkavu, and 9 families were found only in Iringole Kavu.

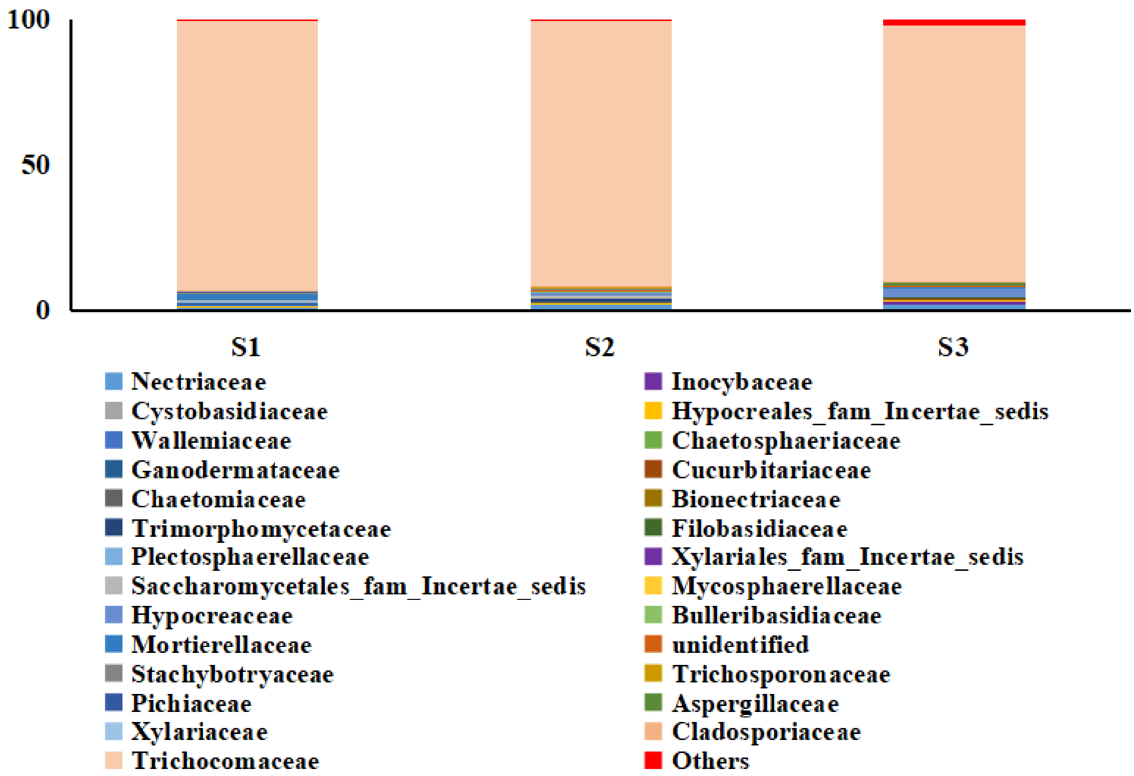

Figure 44. Graph showing the taxonomic assignment at the family level

At the genus level (Figure 45), *Talaromyces* of Trichocomaceae family predominated the sample with 28,134 OTU in Iringole Kavu, 9,427 OTU in Kollakal Thapovanam and 48493 OTU in Poyilkavu. A Barplot was used to show the abundance of each genus in the sample (Figure 46 to 48), which clearly showed the predominance of the *Talaromyces* genus over the others. Other abundant genera in

Iringole Kavu were *Mortierella, Neocarmospora*, *Acremonium* and *Candida* of Incertae sedis. In Kollakal Thapovanam and Poyilkavu, following *Talaromyces*, *Neocarmospora* and *Trichoderma* were abundant.

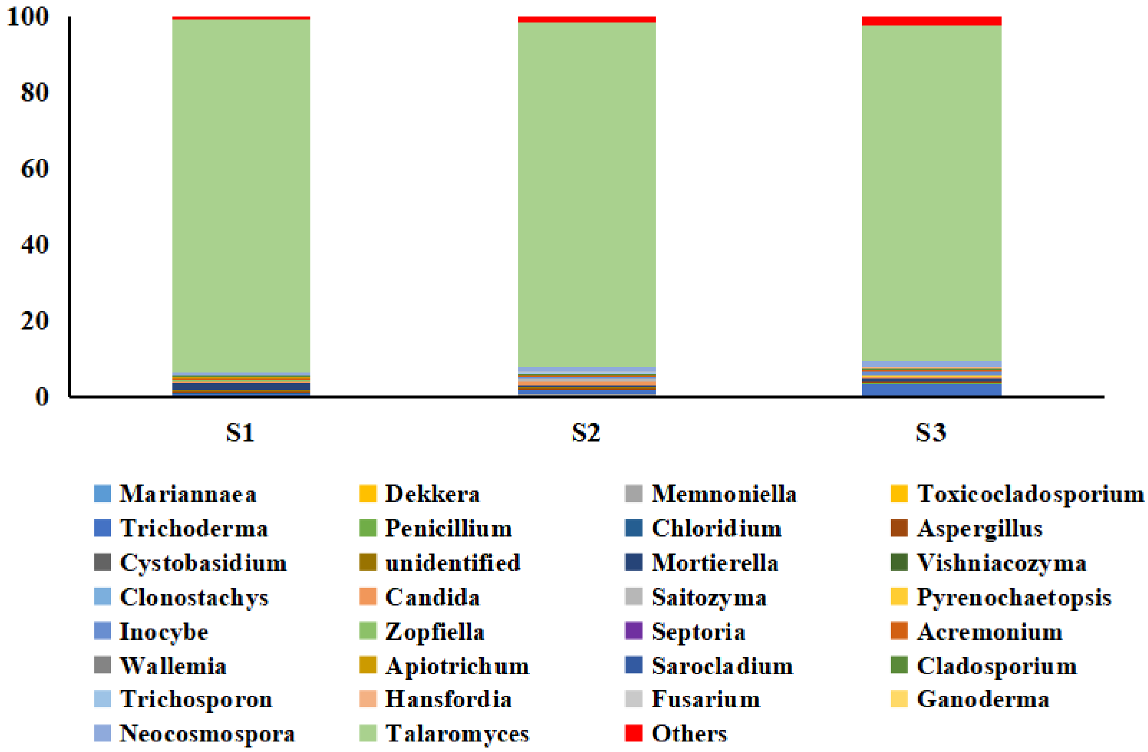

Figure 45. Graph showing the taxonomic assignment at the genus level

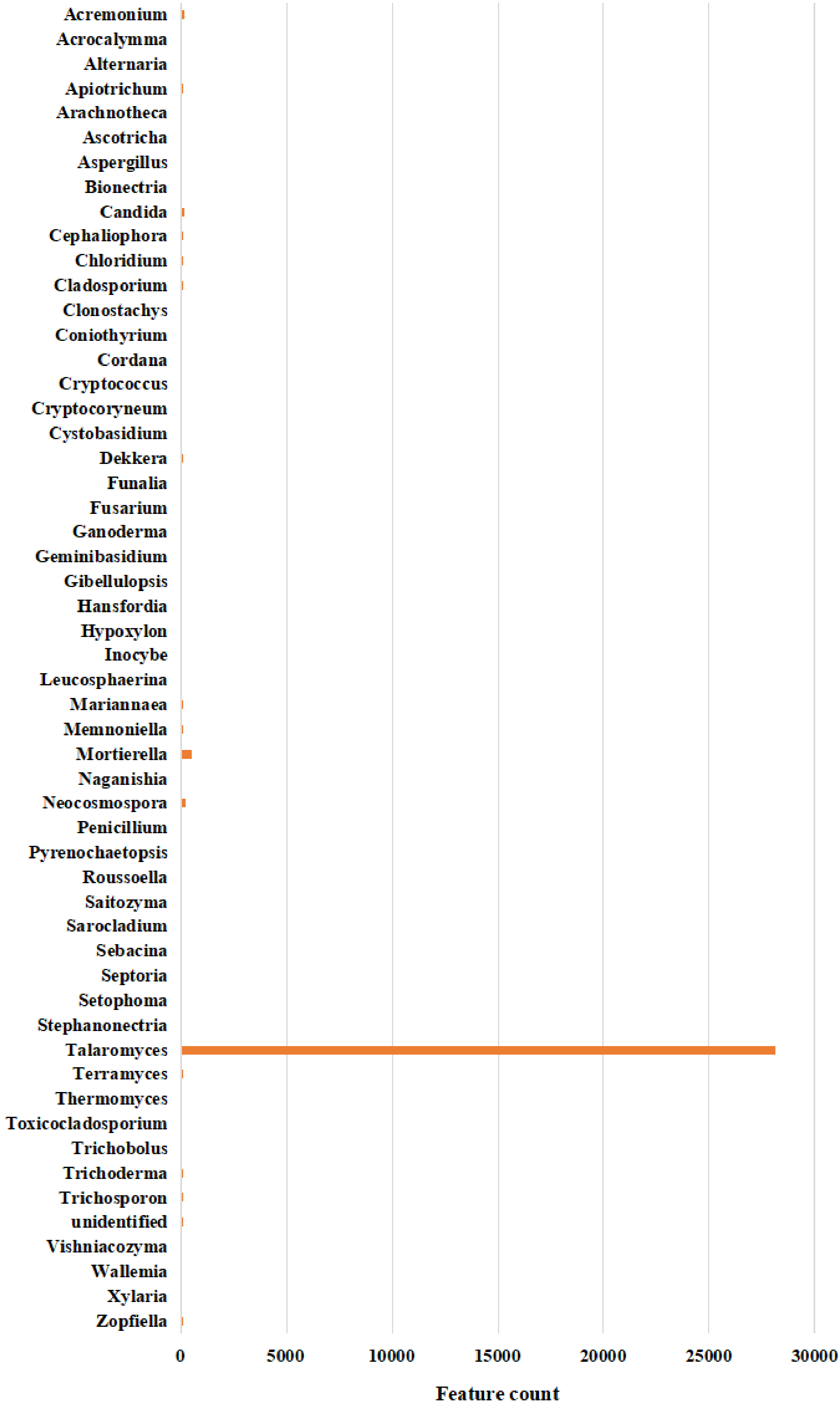

Figure 46. Barplot of Iringole Kavu at the genus level

Figure 47. Barplot of Kollakal Thapovanam at the genus level

Figure 48. Barplot of Poyilkavu at the genus level

A Venn diagram was made at the genus level (Figure 49), showing that 30 genera were common in all three sacred groves. Four genera were found only in Iringole Kavu and Kollakal Thapovanam, six genera were found only in Iringole Kavu and Poyilkavu whereas 16 genera were found only in Kollakal Thapovanam and Poyilkavu. 32 genera were seen only in Kollakal Thapovanam whereas 14 genera were seen only in Iringole Kavu, and 18 genera only in Poyilkavu. A Heat map (Figure 50) was prepared at the genus level, where each row corresponds to a genus (OTU), and each column corresponds to a sample. The higher the relative abundance of an OTU in a sample, the more intense the colour at the corresponding position in the Heat map. Here, yellow represents more abundance, while blue represents less abundance.

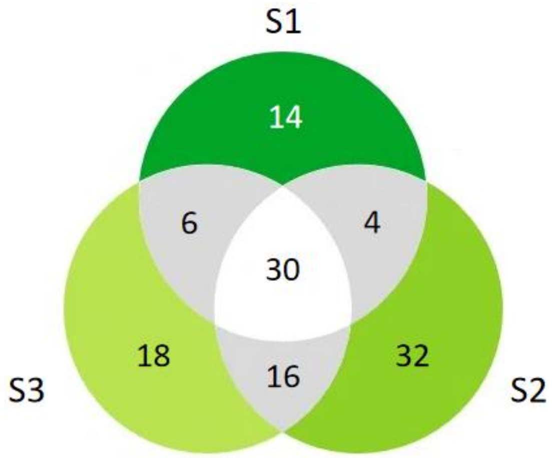

Figure 49. Venn diagram at the genus level

A total of 135 species were identified from the sacred groves. In that *Neocarmospora falciformis, Trichoderma lixii* and *Candida ethanolica* were some of the common and abundant species found in all the sacred groves. But *Mortierella minutissima* was the species that dominates in Iringole Kavu, which was absent in other sacred groves. However, 1269 OTUs remain unidentified at the species level (Figure 51).

Out of 135 species identified, Kollakal Thapovanam had the highest number of species (88). 25 species were common to all the sacred groves. 44 species were seen only in Kollakal Thapovanam, 20 species were found only in Poyilkavu, and another 20 species were found only in Iringole Kavu.

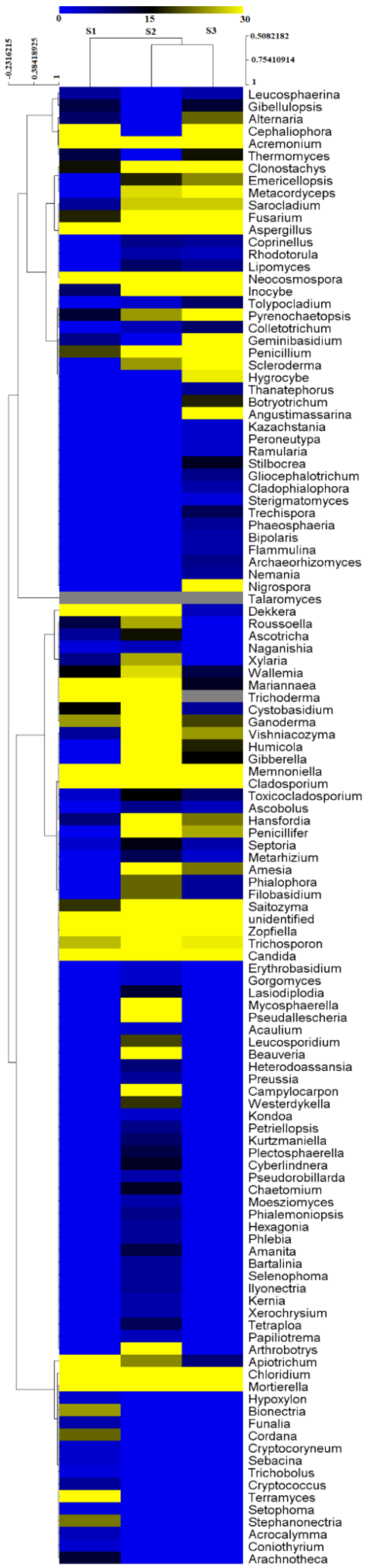

Figure 50. Clustered Heat map at the Genus level

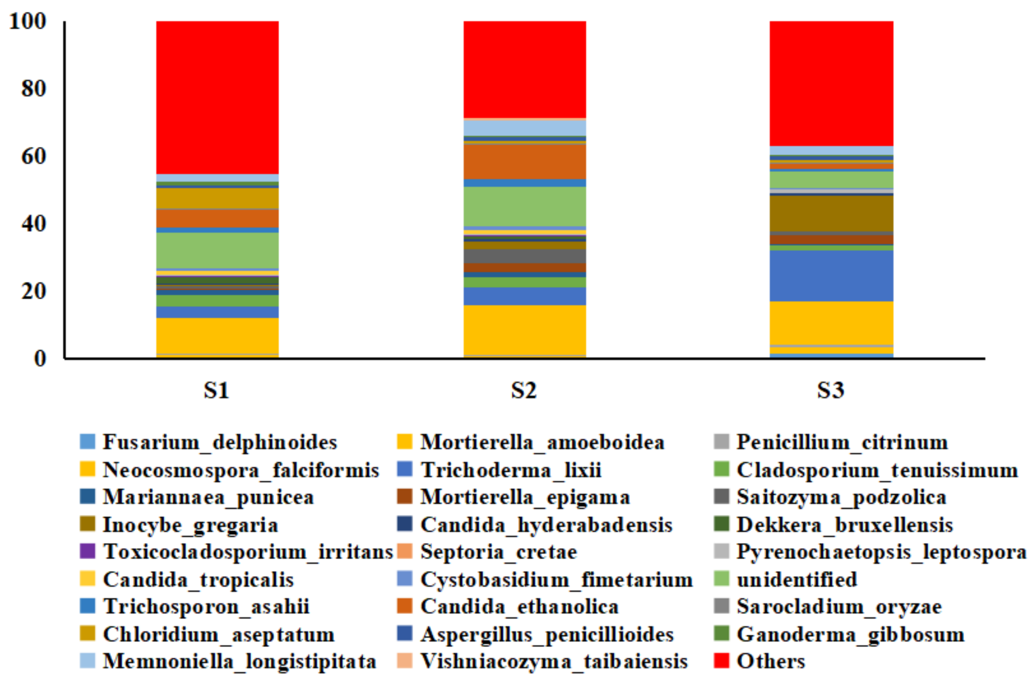

Figure 51. Graph showing the taxonomic assignment at the species level

4.7.4 Diversity Analysis

A phylogenetic tree was prepared (Annexure 75–77) using the FastTree program, which computed phylogenetically-based alpha diversity metrics. The alpha diversity analysis estimates the abundance and diversity of species in environmental communities, as well as the number of species in the fungal community. The alpha diversity indices were calculated and are given in Table 20.

Table 20: Alpha diversity indices

	Chao 1	Observed features	Shannon index	Simpson index
Iringole Kavu	133	133	1.408152694	0.289899993
Kollakal Thapovanam	235	235	1.730943685	0.324326373
Poyilkavu	179	179	1.816606482	0.356734908

The richness estimators, such as Chao 1 and Observed features, revealed that Kollakal Thapovanam has the highest species richness, followed by Poyilkavu and

Iringole Kavu. This indicates that Kollakal Thapovanam was richer in fungal species. However, according to the Shannon and Simpson indices, Poyilkavu exhibits higher values. Therefore, based on the Shannon index, Poyilkavu has a rich biodiversity compared with the other two sacred groves. According to the Simpson index, Poyilkavu has a higher value, indicating higher dominance.

The Rarefaction curve of observed features (Figure 52), the Shannon rarefaction curve (Figure 53), and the rank-abundance curve were plotted (Figure 54). In the Rarefaction curve of observed features, the plateauing of the curves revealed that the generated sequence reads and identified OTUs were adequate to encompass the fungal diversity within these three samples. The Rarefaction curve of the Shannon index indicates that with the increase in sample size, the rate of new species also increases. The Rank Abundance curve reflects an even distribution of fungal taxa in all three sacred groves due to the shallow gradient of the curve.

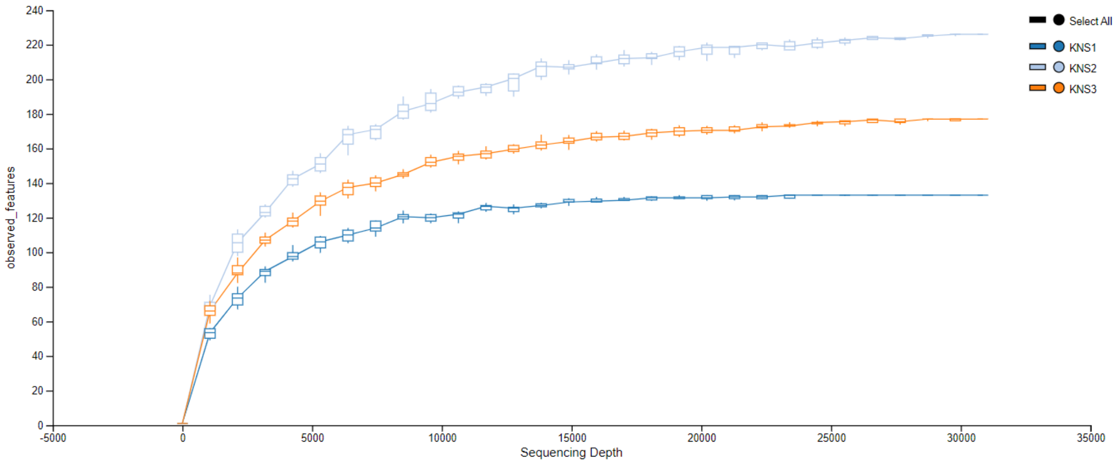

Figure 52. Graph showing the rarefaction curve of observed features

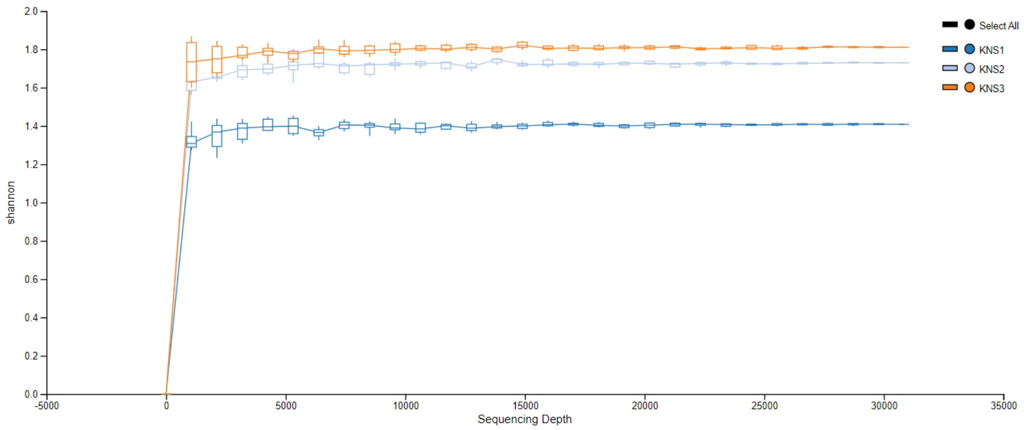

Figure 53. Graph showing the Shannon rarefaction curve

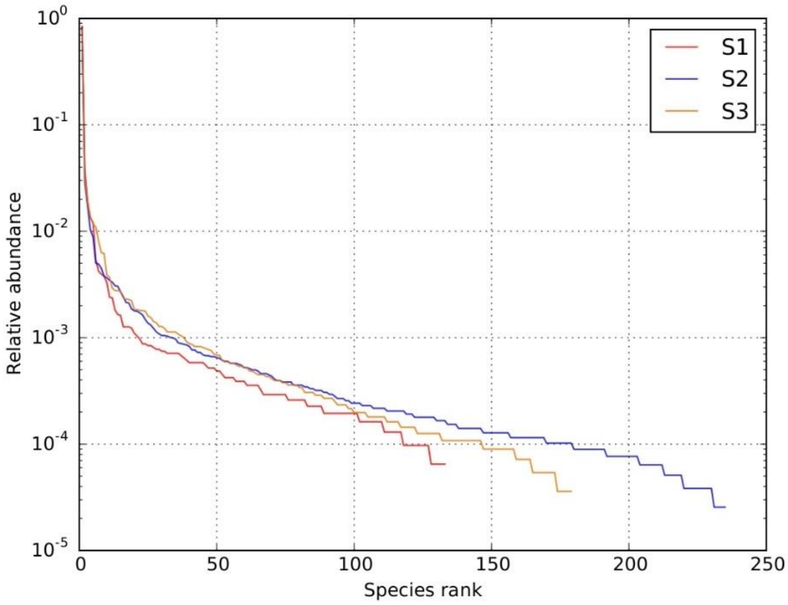

Figure 54. Graph showing the rank abundance curve

The Beta Diversity analysis was calculated to measure the in-between sample diversity and is given in Table 21. The Bray-Curtis dissimilarity index for all three sacred groves falls between 0 and 1, indicating that they share common species but not all are common. The Jaccard similarity index analysis shows that Iringole Kavu and Kollakal Thapovanam are more similar, and Iringole Kavu and Poyilkavu are the less similar ones when compared with others.

Table 21: Beta diversity indices

Jaccard distance-matrix			
	S1	S2	S3
S1	0	0.911242604	0.844444444
S2	0.911242604	0	0.884097035
S3	0.844444444	0.884097035	0

Bray-Curtis distance-matrix			
	S1	S2	S3
S1	0	0.471060755	0.329895715
S2	0.471060755	0	0.264617842
S3	0.329895715	0.264617842	0

Weighted UniFrac distance-matrix			
	S1	S2	S3
S1	0	0.049822543	0.064852861
S2	0.049822543	0	0.058776271
S3	0.064852861	0.058776271	0

Unweighted UniFrac distance-matrix			
	S1	S2	S3
S1	0	0.720107757	0.632633772
S2	0.720107757	0	0.659475098
S3	0.632633772	0.659475098	0

The PCoA analysis of Weighted UniFrac (Figure 55), Unweighted UniFrac (Figure 56), Jaccard (Figure 57), and Bray-Curtis (Figure 58) reveals that the objects were not close to each other, and hence these three sacred groves were very much different from one another.

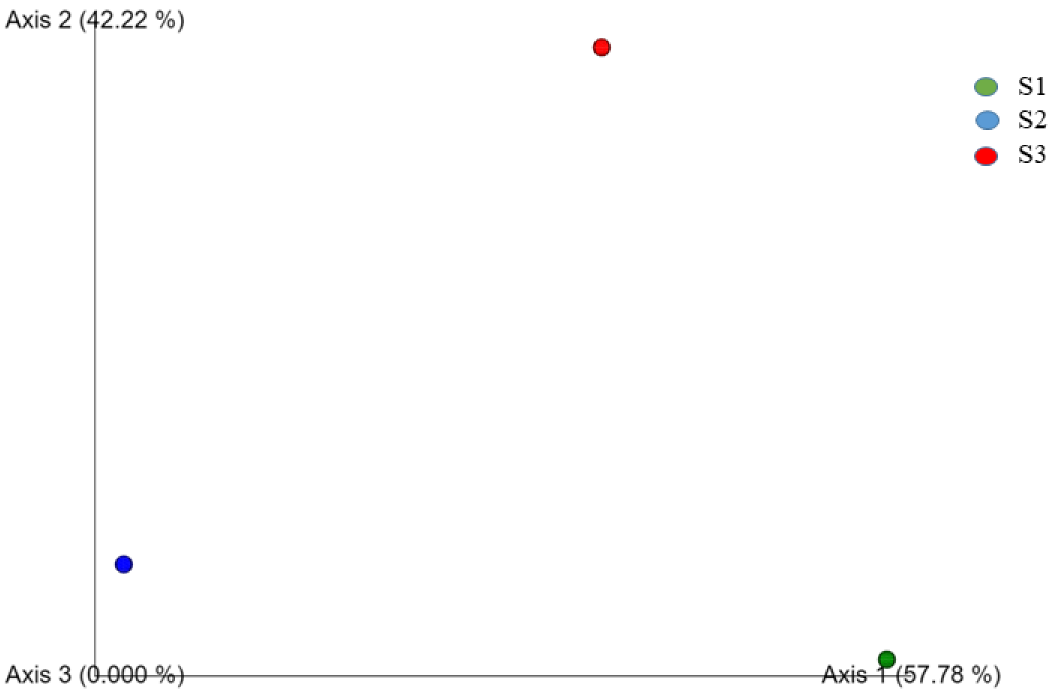

Figure 55. Scatter plot of Weighted UniFrac PCoA analysis

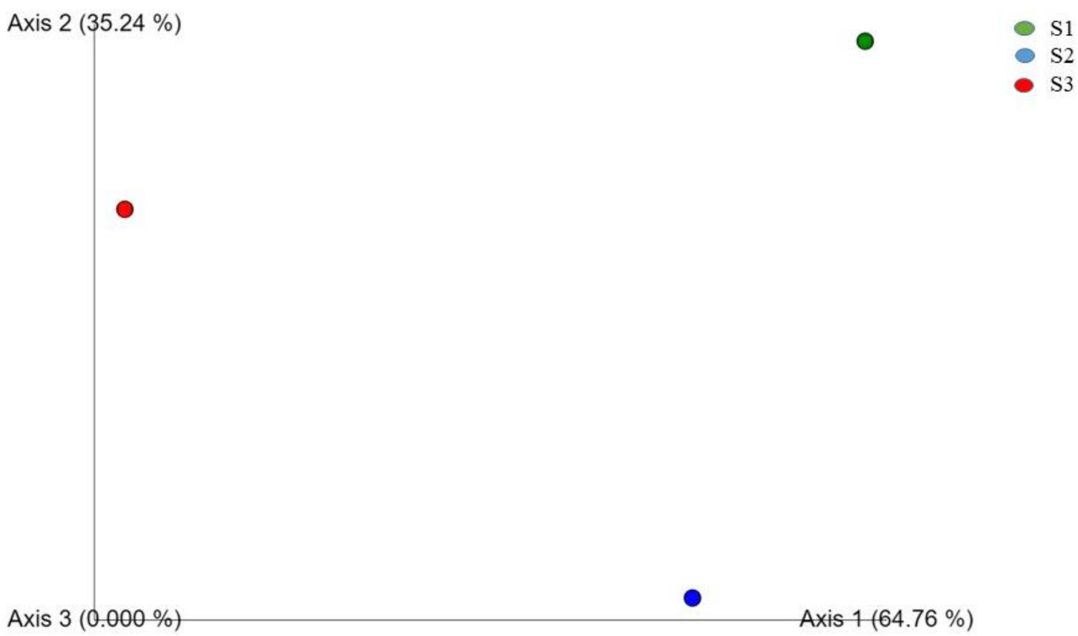

Figure 56. Scatter plot of Unweighted UniFrac PCoA analysis

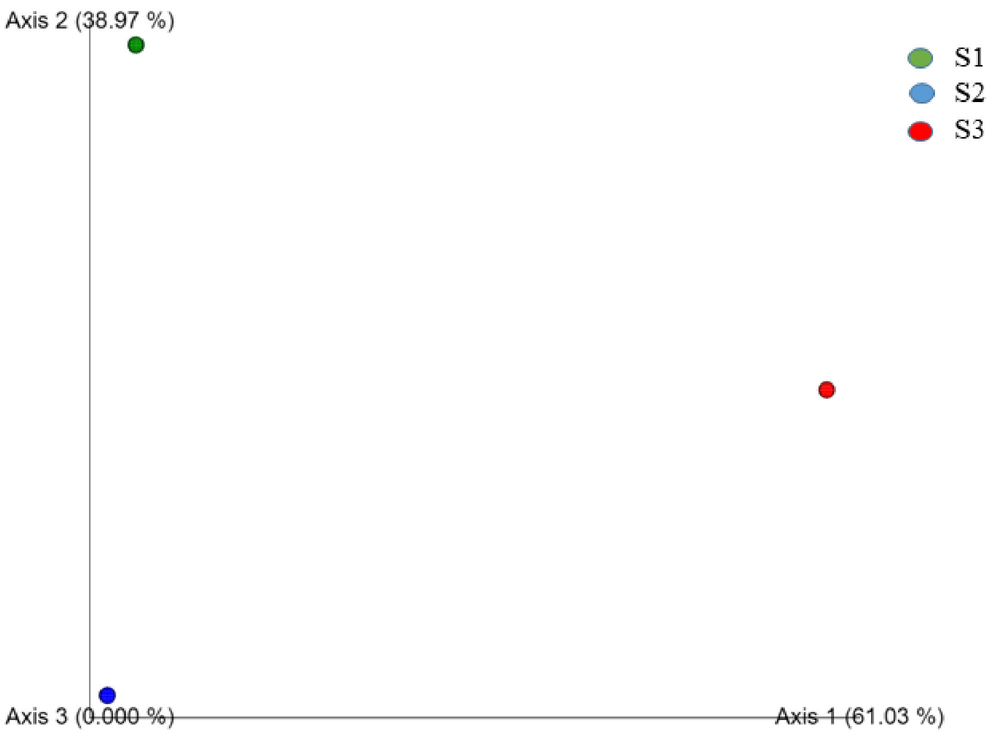

Figure 57. Scatter plot of Jaccard PCoA analysis

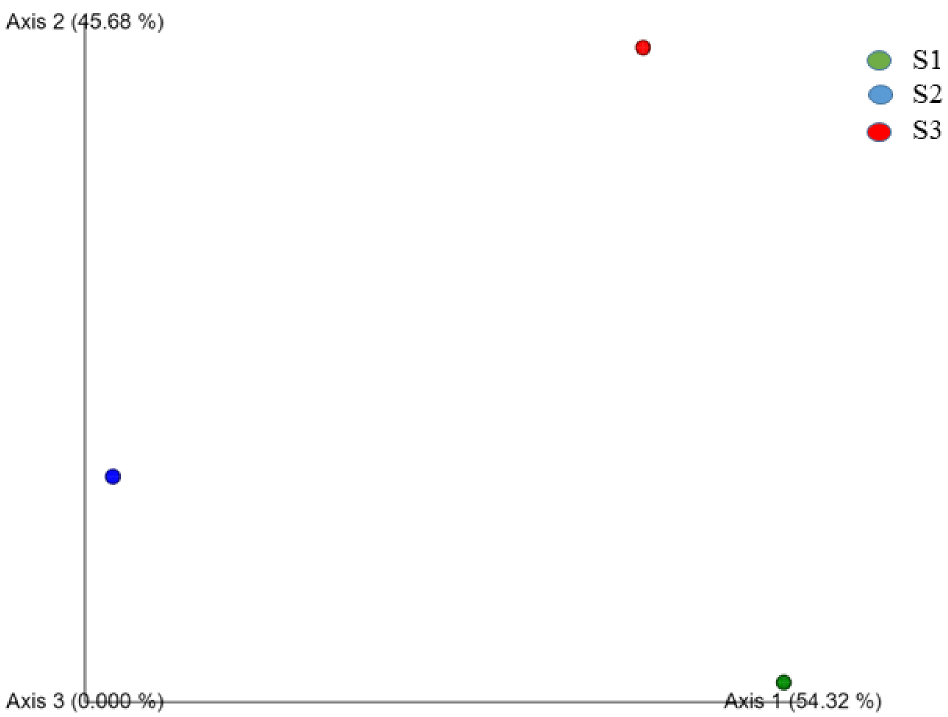

Figure 58. Scatter plot of Bray-Curtis PCoA analysis

Chapter 5

Discussion

Sacred groves are areas of dense vegetation that preserve unique biodiversity. They show greater potential for biodiversity than well-preserved evergreen forests (Induchoodan, 1998), and soil fungi are essential in supporting this rich vegetation (Bandgar and Patil, 2019). Hence, this study focuses on the soil fungi found in three sacred groves located in different regions of Kerala: Iringole Kavu in Ernakulam District, Kollakal Thapovanam in Alappuzha District, and Poyilkavu in Kozhikode District (Figures 1 and 2). Our research represents the first comprehensive analysis and comparison of soil fungal diversity in these sacred groves, highlighting their unique ecological significance and interrelationships.

5.1 Taxonomic Studies

The study identified a total of 168 species belonging to 34 genera, along with four unidentified species and two non-sporulating fungi (Table 5, Plates 1–44). Exploring these fungal treasures in sacred groves can enhance our understanding of biodiversity and contribute positively to the nation's natural heritage.

The findings revealed that 94% of the isolated fungi belong to the Ascomycota phylum, making it the most prevalent group in the soil. The significant role of these fungi in various soils, likely due to their contribution to the degradation and recycling of dead plant material, helps explain their dominance and widespread presence. Mucoromycota was the second phylum, accounting for only 6% of the isolated fungi. This result aligns with earlier research conducted by Devi et al. (2012) and Devi and Dkhar (2014). Of the 168 taxa documented in this study, 16 species are newly reported for India, and 18 species are new to Kerala.

5.2 Quantitative Analysis

In the current study, Eurotiomycetes was the most abundant class, followed by Sordariomycetes and Mucoromycetes. Conversely, Saccharomycetes and Leotiomycetes were the least abundant classes (Figure 3). Among the fungal orders studied, Eurotiales emerged as the most abundant, followed by Hypocreales. In contrast, the least abundant orders were Cladosporiales, Helotiales, Saccharomycetales, and Diaporthales. The genus *Penicillium*, of family Aspergillaceae, comprises 49 species and was the most prevalent among the studied genera. The genus *Aspergillus* was the second most abundant, with 30 identified species. Sankaran and Balasundaran (2000) supported these findings.

The spatial and seasonal distribution of taxa (Table 6 and Figure 4) indicates that Iringole Kavu has the highest species diversity, with a total of 105 species, followed by Poyilkavu and Kollakal Thapovanam. These findings indicate that fungal populations are more prevalent in evergreen forests compared to semi-evergreen forests, and in undisturbed forests rather than disturbed ones. Furthermore, the once prevalent heritage of fungal species has contributed to the high fungal diversity found in natural groves, while man-made groves, lacking this heritage, exhibit lower diversity. These observations align with the findings of Arunachalam et al. (1999) and Sharma et al. (2015).

Seasonally, (Table 6 and Figure 5), the highest number of species was recorded in Pre 2 of Iringole Kavu, and in the Mo 2 of both Kollakal Thapovanam and Poyilkavu. This indicates that soil conditions, particularly moisture content, are significant determinants of fungal diversity, as moisture content was notably higher during these seasons, contributing to the observed high species diversity, supported by Tresner et al. (1954) and Griffin (1963).

Iringole Kavu and Poyilkavu exhibit greater similarities, attributable to their status as natural sacred groves. Also, 59 species are found exclusive to Iringole Kavu, 29 to Kollakal Thapovanam, and 26 in Poyilkavu, which were depicted in Venn diagrams (Figure 6). These findings indicate that undisturbed sacred groves harbour a greater fungal diversity than disturbed forests, with minimal disturbance being a key factor for biodiversity richness. Furthermore, the results highlight that natural habitats are more species-rich than man-made environments. This view was supported by findings from Devi and Dkhar (2014) and Sukumaran et al. (2008).

The list of genera exclusive to sacred groves further emphasises the biodiversity inherent in these natural habitats (Table 7). Moreover, these results suggest that the complex vegetation and abundant organic matter in these environments provide various substrates, allowing different fungal species to coexist. This leads to a high number of restricted species in sacred forests, supported by the observations made by Wicklow and Whittingham (1974) and Christensen (1981).

A total of 14 species were identified as abundant across the three sacred groves examined in this study (Table 8). *Purpureocillium lilacinum* was the most prevalent fungus, followed by *Trichoderma harzianum, Aspergillus flavus*, and *Aspergillus niger*. Notably, *Purpureocillium lilacinum* has not been previously identified as the most abundant species, likely due to the influence of host specificity and tree dominance on fungal species in the soil. This aligns with findings by Schmitz et al. (1989) and Zhang et al. (2011).

In analysing the spatial variation of fungi, Poyilkavu had the highest Colony Forming Units (CFU), followed by Iringole Kavu and Kollakal Thapovanam. This suggests that CFU was higher in undisturbed sacred groves than in disturbed ones. Regarding seasonal variations, Poyilkavu and Kollakal Thapovanam showed fluctuations in CFU, while Iringole Kavu's fungal population remained stable, likely due to its evergreen nature and minimal leaf shedding. In contrast, the other groves experienced more instability in fungal populations, likely influenced by climate variations (Figure 7).

5.3 Diversity Analysis

A comprehensive analysis of both spatial and seasonal diversity was conducted. Different diversity indices, such as Simpson's dominance index, Shannon-Wiener index, Margalef Richness index, and Pielou’s Evenness index, were calculated across seasons and sites.

In the spatial diversity analysis (Table 9), Iringole Kavu exhibited the highest values for all examined indices, indicating a high level of diversity and a balanced ecosystem. This suggests that undisturbed sacred groves harbour greater species richness, resulting in a more stable ecosystem. Our findings are consistent with those of Diamandis et al. (2021) and Seena (2021).

The seasonal diversity analysis (Tables 10–12) demonstrated that species diversity, dominance, and richness varied with seasons. In Iringole Kavu, species diversity peaked during the pre-monsoon season. This observation aligns with the findings of Guleri et al. (2010). Conversely, Kollakal Thapovanam and Poyilkavu had higher diversity in the monsoon season. This variation was attributed to soil moisture content: moisture levels in Iringole Kavu were elevated during the pre-monsoon season, while they were higher during the monsoon in Kollakal Thapovanam and Poyilkavu. Thus, it can be concluded that habitat differences and soil characteristics influence fungal preferences seasonally. The Bray-Curtis similarity index (Table 13) shows that while common species are present across groves, not all species thrive in every location. The presence of common species may be due to their ability to thrive in varying environmental conditions.

5.4 Multivariate Analysis

5.4.1 Hierarchical Cluster Analysis (HCA)

In the spatial Hierarchical Cluster Analysis (HCA), Iringole Kavu and Poyilkavu are more similar to each other, as they are grouped together in the dendrogram. In contrast, Kollakal Thapovanam forms a separate group, highlighting its distinct differences from the other two sacred groves. This shows that the man-made grove stands separate (Figure 8).

The seasonal analysis reveals distinct differences across various seasons. In the case of Iringole Kavu and Poyilkavu (Figures 9 & 11), the initial pre-monsoon season emerges as a distinct category, while the remaining seasons are classified together into a separate group. For Kollakal Thapovanam (Figure 10), the post-monsoon season was markedly different from the others, forming an independent group. These findings reveal that sacred groves show seasonal variation in fungal population.

5.4.2 Non-metric Multidimensional Scaling (NMDS) Analysis

The NMDS analysis conducted across different sites and seasons aligns with the results of Hierarchical Cluster Analysis. Site-wise NMDS analysis (Figure 12) reveals that each sacred grove was unique and possessed distinct flora, as they are positioned apart from one another. Notably, Kollakal Thapovanam was situated far from the other two sacred groves, highlighting its dissimilarity. In the seasonal NMDS analysis of Iringole Kavu (Figure 13), the pre-monsoon season stands out distinctly, showcasing its unique characteristics compared to the other seasons. In Kollakal Thapovanam (Figure 14), the post-monsoon season also features a unique floral composition, as it was separated from the other seasons. In Poyilkavu (Figure 15), all seasons are distinctly separated from one another, emphasising their uniqueness. These findings establish that sacred groves have distinct spatial and seasonal variations in their fungal populations.

5.5 Physicochemical Analysis of Soil

A total of twelve physicochemical parameters were examined over three seasons for two years.

5.5.1 Temperature

The analysis (Figure 19) indicates that the temperature range was quite similar across all three sacred groves. The complete tree canopy in these areas prevents direct sunlight, resulting in minimal temperature variation. Throughout the study area, temperatures range from 20°C to 28.87°C, which aligns well with the ideal temperature for fungal growth, as supported by Siddiqui (2012). As a result, we can conclude that the soil temperatures in these sacred groves positively influence soil fungal diversity. Several researchers support our findings, including Panda et al. (2009), Guleri et al. (2010), and Paulina et al. (2016).

5.5.2 pH

The study (Figure 20) indicates that the pH levels in all the sacred groves are quite similar. The observed pH range of 4.35 to 5.86 suggests that an acidic pH is favourable for fungal growth in these areas. This was supported by Fresquez et al. (1988) and Devi et al. (2012). Seasonal variations in pH levels were minimal within these groves; however, they led to fluctuations in fungal diversity across different seasons, supported by Siddiqui (2012).

5.5.3 Moisture Content

The moisture content analysis (Figure 21) reveals significant differences across both space and time. In Iringole Kavu, the high moisture content, resulting from low light penetration, correlates with greater fungal diversity. Conversely, the lower moisture levels in Kollakal Thapovanam, which are attributed to high human impact, lead to reduced fungal diversity, as supported by the findings of Chandrashekara et al. (2018). Therefore, this study underscores moisture content as a critical factor influencing fungal diversity. This observation aligns with Tresner et al. (1954) and Griffin (1963). However, Chauhan et al. (1985) and Devi et al. (2012) reported a negative correlation between soil moisture and fungal diversity.

5.5.4 Organic Carbon

The spatial and seasonal variation analysis in organic carbon levels (Figure 22) demonstrates significant spatial differences. Iringole Kavu has the highest levels of organic carbon, followed by Poyilkavu and Kollakal Thapovanam. This variation was attributed to the lack of plant residue removal in Iringole Kavu and Poyilkavu, whereas plant residues are removed from Kollakal Thapovanam. Thus, the study concludes that elevated organic carbon levels contribute to increased species diversity. Furthermore, only Kollakal Thapovanam exhibited significant seasonal variations in organic carbon, impacting the fungal flora across different seasons, which aligns with the findings of Chandrashekara et al. (2018) and Panda et al. (2009).

5.5.5 Electrical Conductivity

The analysis of spatial and seasonal variations in electrical conductivity (see Figure 23) shows that the values recorded in all the sacred groves are minimal. Since these conductivity values are relatively low, we can conclude that they do not significantly impact the soil fungal population in these groves.

5.5.6 Water Holding Capacity

The study (Figure 24) reveals that Iringole Kavu has the highest capacity, followed by Poyilkavu and Kollakal Thapovanam, and the peak capacity was observed during the Po 2 period. This was due to its rich species diversity because soil fungi positively influence water holding capacity by enhancing soil structure, increasing organic matter, and improving water infiltration (Querejeta, 2017).

5.5.7 Available Nitrogen

The study reveals significant fluctuations in nitrogen levels (Figure 25). Higher concentrations of available nitrogen were observed in Poyilkavu and Iringole Kavu. Seasonally, increased levels were noted during the Pre 2 season in Iringole Kavu and Kollakal Thapovanam, as well as in the Mo 2 season in Poyilkavu. Thus, the availability of nitrogen positively influences fungal diversity in both spatial and seasonal contexts and consistent with the research of Di Lonardo et al. (2020) and Shameemullah (1971).

5.5.8 Available Phosphorus

The analysis of spatial and seasonal variations in available phosphorus (Figure 26) demonstrates that available phosphorus negatively correlates with fungal diversity. Iringole Kavu has the lowest levels of available phosphorus, which correspond to high species diversity. In contrast, Kollakal Thapovanam consistently exhibits the highest levels of phosphorus, which are associated with lower fungal diversity. The study also shows that available phosphorus in the soil increases from plantation areas to deciduous forests, while tending to be lower in evergreen forests, aligning with those of Zhu et al. (2021).

5.5.9 Available Potassium

In this study, available potassium positively correlates with fungal diversity (Figure 27). Iringole Kavu records the highest levels of available potassium, which can be attributed to its rich species diversity, while Kollakal Thapovanam shows the lowest levels, linked to its comparatively lower species diversity. This observation was supported by the works of Pinzari et al. (2022) and Shameemullah (1971).

5.5.10 Exchangeable Calcium

The study shows that exchangeable calcium positively influences the fungal diversity (Figure 28). Because the highest calcium levels in Iringole Kavu correspond with its greatest species diversity. Additionally, the seasonal variations in exchangeable calcium levels at Kollakal Thapovanam and Poyilkavu led to fluctuations in species diversity within these groves. In contrast, species diversity in Iringole Kavu remained relatively stable throughout the seasons, as no significant variation in exchangeable calcium was observed, supported by the findings of Gnanasekaran et al. (2015).

5.5.11 Exchangeable Sodium

The analysis of spatial and seasonal variations in exchangeable sodium indicates a negative correlation between exchangeable sodium levels and fungal diversity (Figure 29). Specifically, all sacred groves with high fungal diversity showed low levels of exchangeable sodium. Also, the seasonal variations in fungal diversity correlated with changes in exchangeable sodium levels. This finding aligns with Zhang et al. (2019) and Gao et al. (2022). However, it contradicts the results from Chauhan et al. (1985), who reported a positive correlation between exchangeable sodium and the number of fungi.

5.5.12 Soil Texture

The soil texture analysis revealed that soil texture varied not only between different sacred groves but also across various seasons within each grove (Table 14). This variation contributed to distinct fungal compositions in the various sacred groves and during different seasons.

5.6 Correlation Analysis

5.6.1 Canonical Correspondence Analysis

Canonical Correspondence Analysis (CCA) performed across three seasons over two years (Figures 30–32) revealed that the composition of fungal communities closely correlates with seasonal changes and localised soil physicochemical characteristics. Certain parameters consistently influence fungal diversity in specific locations, while they prove insignificant in others, reflecting the site-specific ecological dynamics of individual groves. Out of the 11 parameters examined, temperature, nutrient availability, moisture content, and exchangeable ions were identified as significant factors driving fungal diversity. Importantly, temperature, exchangeable calcium, and exchangeable sodium affected fungi across all seasons and locations. In contrast, parameters such as available nitrogen, organic carbon, and pH showed more localised effects. This highlights the ecological distinctiveness of each grove and emphasises the significant role of both localised soil conditions and seasonal changes in shaping the fungal biodiversity found in sacred groves. Fungal genera revealed distinct niche differentiation; some were closely linked to specific environmental gradients, while others demonstrated ecological plasticity by occupying niches beyond the variables measured. This combination of deterministic environmental filtering and stochastic adaptability implies a complex relationship between microbial communities and their surroundings that varies not only by species but also by site and season. These patterns were consistently supported by Hierarchical Cluster Analysis (HCA) and Non-metric Multidimensional Scaling (NMDS), reinforcing the robustness of the findings. Collectively, the study contributes deeper insights into how sacred groves function as reservoirs of microbial diversity, governed by finely balanced ecological processes, and emphasises the importance of conserving these ecosystems.

5.6.2 Indicator Species Analysis

The Indicator Species Analysis conducted across various sites and seasons revealed that each sacred grove and season has unique indicator species that reflect their environmental conditions (Figures 33–36), indicating a high degree of fungal specificity. These findings align with the results from CCA, which shows that the abundance or presence of specific species was influenced by particular physicochemical parameters. Therefore, the variations in fungal diversity and occurrence specificity are likely due to differences in environmental conditions and vegetation among these sacred groves. We conclude that each sacred grove exhibits seasonal variations, hosts its unique environment, and supports distinct biodiversity. Furthermore, minor habitat changes can lead to the extinction of certain fungi. The IUCN Red List now includes over 1,000 fungi species, emphasising how deforestation, agricultural expansion, and urban development are driving their global decline (IUCN, 2025).

5.7 Metagenomics Analysis

The metagenomic analysis of soil samples using ITS-124 Amplicon Illumina Sequencing revealed the presence of five fungal phyla. The taxonomic classification of OTUs indicates that the abundance and composition of soil fungi vary among the sacred groves, even though the same phyla were observed. Ascomycota was the most dominant phylum, followed by Basidiomycota (Figures 38–41). The most prominent class was Eurotiomycetes, followed by Sordariomycetes (Figure 42), corroborating earlier findings by Hedeler et al. (2007). A total of 441 taxa were identified in this study, with 205 classified at the genus level and 236 remaining unidentified (Table 19). The class Archaeorhizomycetes, identified from Poyilkavu, adds to the existing knowledge of its occurrence.

The genus *Talaromyces*, belonging to the family Trichomaceae, was dominant in all three soil samples (Figure 45). However, *Penicillium* was the most abundant genus in the serial dilution technique. This discrepancy may arise due to *Talaromyces* being less responsive in the culture media, and it could also stem from misidentification, as *Talaromyces* includes the teleomorph of the genus *Penicillium*. Our study reveals that the high incidence of *Talaromyces* positively influences plant diversity in sacred groves, as these fungi are recognised as biocontrol agents against plant pathogenic fungi and as anti-insectants (Nicoletti and Becchimanzi, 2021; Dethoup et al., 2007). And *Neocarmospora falciformis*, *Trichoderma lixii,* and *Candida ethanolica* were the abundant species (Figure 51). The bar plot (Figures 46–48) also illustrates the dominance of the genus *Talaromyces* across all groves; however, the composition of genera varied between them. A total of 32 genera were unique to Kollakal Thapovanam, 18 to Poyilkavu, and 14 to Iringole Kavu (Figure 49). This highlights that certain groups of fungi are highly specific to particular sacred groves while being absent from others.

The diversity analysis (Table 20) revealed that Kollakal Thapovanam exhibits high species diversity. However, the serial dilution method indicated that Iringole Kavu had the highest diversity. This discrepancy was likely due to the rich humus content found in the soil of Iringole Kavu. This increased humus was a result of the practice of not removing plant residues, which enhances soil fertility and microbial activity. Consequently, these conditions may complicate processes such as DNA isolation, as noted by Wnuk et al. (2020). The comparative analysis (Table 21) showed that certain species were found exclusively in specific groves, despite the presence of shared species across the sacred groves. The PCoA analysis revealed that each grove was distinct (Figures 55–58).

Chapter 6

Summary and Conclusion

The present study analyses and compares the diversity, composition, and abundance of soil fungi from three sacred groves in Kerala: Iringole Kavu in Ernakulam District, Kollakal Thapovanam in Alappuzha District, and Poyilkavu in Kozhikode District. This research marks the first investigation of soil fungi in the sacred groves of Kerala, conducted over three seasons across two years. The soil samples were collected using a composite soil sampling method, and serial dilution technique and metagenomics analysis were employed to isolate and identify the soil fungi. The study identified 34 genera and 168 species of fungi belonging to six different classes. Additionally, four unidentified species and two non-sporulating fungi were collected. Of the 168 taxa recorded in this study, 16 species are reported for the first time in India, and 18 species are new for Kerala.

Ascomycota emerged as the most dominant phylum, followed by Mucoromycota. The classification included five classes of Ascomycota, with Eurotiomycetes being the most abundant, followed by Sordariomycetes and Mucoromycetes from the Mucoromycota phylum. Moreover, this was further divided into 11 orders and 16 families. The genus *Penicillium* was the most diverse, comprising 49 species, followed by *Aspergillus* with 30 species. Among these, *Purpureocillium lilacinum* was the most abundant species.

The spatial and seasonal analyses of the taxonomic distribution revealed that fungal diversity was high across all studied groves, with Iringole Kavu having the highest number of species (105), followed by Poyilkavu (67) and Kollakal Thapovanam (64). Seasonal analyses indicated that Pre 2 in Iringole Kavu and Mo 2 in both Kollakal Thapovanam and Poyilkavu had the highest species count. Our findings suggest that soil conditions, particularly moisture content, are significant determinants of fungal diversity. Venn diagrams illustrated that Iringole Kavu and Poyilkavu share considerable similarities, with 18 common species due to their classification as natural sacred groves. Moreover, Iringole Kavu hosts 59 exclusive species, Kollakal Thapovanam has 29, and Poyilkavu has 26. Additionally, Iringole Kavu has eight unique genera, while Poyilkavu has four, and Kollakal Thapovanam has two. This indicates that Iringole Kavu boasts greater species richness and emphasises that natural habitats support more species than man-made environments.

The spatial and seasonal quantitative analysis revealed that Poyilkavu had the highest Colony Forming Units (CFU), followed by Iringole Kavu, while Kollakal Thapovanam recorded the lowest due to anthropogenic disturbances. In the seasonal analysis, the population in Iringole Kavu remained stable due to the grove's evergreen nature, as it experiences no seasonal leaf shedding. The study also examined spatial and seasonal changes in fungal diversity. Iringole Kavu exhibited the highest values across all indices, indicating a rich and balanced ecosystem. Seasonal analysis demonstrated that species diversity, dominance, and richness were influenced by seasonal changes. The Bray-Curtis similarity index revealed that while these sacred groves share some common species, not all species are found in every location, showing their ability to thrive in varying environmental conditions.

Hierarchical Cluster Analysis grouped similar seasons and sites, revealing distinct patterns: Iringole Kavu and Poyilkavu were clustered together, while Kollakal Thapovanam formed a separate group. In Iringole Kavu and Poyilkavu, Pre 1 stood out as a unique group, whereas in Kollakal Thapovanam, post-monsoon was identified as a separate group. The Non-metric Multidimensional Scaling confirmed these findings, indicating that each sacred grove was different and possessed unique fungal flora. Additionally, fungal diversity varied with each season within the groves.

The soil physicochemical parameter analysis indicated a positive correlation between soil fungi and factors like moisture content, organic carbon, water holding capacity, available nitrogen, available potassium, and exchangeable calcium. These parameters were found to be higher in Iringole Kavu, indicating a greater diversity of soil fungi in Iringole Kavu. Sacred groves maintain optimal temperature and acidic pH throughout the seasons, which results in high fungal diversity. Conversely, electrical conductivity, available phosphorus, and exchangeable sodium show a negative correlation with soil fungi. Soil texture varied between groves and seasons, leading to distinct fungal compositions in the various sacred groves at different times of the year.

Canonical Correspondence Analysis (CCA) demonstrated differing influences on fungal diversity across sacred groves and seasons, with some species extending beyond the examined parameters. CCA also indicated habitat preferences for the species identified in these sacred groves. These findings aligned with results from

Hierarchical Cluster Analysis (HCA) and Non-metric Multidimensional Scaling (NMDS) analysis. The indicator species analysis revealed that each sacred grove and season has unique indicator species that reflect their environmental conditions, indicating a high degree of fungal specificity. These findings also align with results from CCA.

Metagenomic analysis of soil samples was performed using the ITS-124 Amplicon Illumina Sequencing. Ascomycota was the dominant phylum, followed by Mortierellomycota, Basidiomycota, Chytridiomycota, and Rozellomycota. These fungi are further subdivided into 20 classes, 40 orders, 83 families, 119 genera, and 135 species. Eurotiomycetes was the predominant class. The genus *Talaromyces* from the family Trichomaceae dominated the genera. The most abundant fungal species included *Mortierella minutissima, Neocarmospora falciformis, Trichoderma lixii,* and *Candida ethanolica.* In total, 441 taxa were identified in this study, with 205 specifically classified at the genus level and 236 remaining unidentified. Diversity analysis indicated that Kollakal Thapovanam was rich in fungal species, while Poyilkavu exhibits high biodiversity with significant dominance. In contrast, the serial dilution method revealed that Iringole Kavu has the highest diversity. This difference may be attributed to the high humus content in Iringole Kavu's soil, which complicates DNA isolation. Principal Coordinates Analysis (PCoA) further revealed that each grove is distinct.

The study concludes that the three sacred groves examined from different regions of Kerala showcase unique biodiversity and serve as rich reservoirs of soil fungi. It emphasises that natural habitats tend to be more species-rich than man-made ones. Several fungal species were found exclusively in specific groves and were not present in others, indicating a high level of fungal specificity. Even minor alterations in the habitat can lead to the extinction of certain fungi, underscoring the need to preserve these fungi in their original environments. The research also reveals that the actual number of microfungi remains unknown. Furthermore, it concludes that sacred groves function as miniature forests with rich biodiversity, making it crucial to conserve each grove in its natural state. Overall, this research provides a comprehensive analysis of soil fungal diversity in these vital ecological areas, establishing a foundation for future investigations.

Recommendations

The current study titled "Study of soil fungi from selected sacred groves of Kerala" presents the following recommendations:

1. Create a taxonomic key for identifying fungi at the species level.
2. Molecular analysis to identify unidentified species.
3. A detailed biochemical characterisation of the identified fungal species.
4. A comprehensive analysis of the pharmacognostic properties of the identified fungal species to ascertain their medicinal value.
5. Examine the relationship between plants and fungi.
6. To conduct a detailed study of the endophytic fungi in sacred groves.
7. Ecological niche modelling using QGIS techniques.
8. Determine the conservation status of species using the strategies outlined by the IUCN.

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Annexure

Annexure 1. Table showing the Colony Forming Unit of species identified from Iringole Kavu

Species	ISG											
	Pre 1		Mo 1		Po 1		Pre 2		Mo 2		Po 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Cladosporium cladosporioides	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria atra	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria tenuissima	0	0	0	0	0	0	0.854701	0	0	0	0	0
Aspergillus brevipes	0	0	0	1.010101	0	0	0	0.970874	0	0	0	0
Aspergillus caesiellus	0	0	0	0	0	0	0	0	0	0	0.49505	0
Aspergillus carneus	0	0	0	0	0	0	0	0	0	0	0.990099	0
Aspergillus conicus	0	0	0	0	0	0.473934	0	0	0	0	0	0
Aspergillus coremiiformis	0	0	0	0	0	0	0	0.970874	6.818182	0	0.49505	0
Aspergillus duricaulis	0	16.8	0	0	0	0	0	0.970874	0	0	0	0
Aspergillus flavus	2.158273	5.6	0	0	0	0	0	0.970874	0	0	0.990099	0.735294
Aspergillus flavus var. *columnaris*	0	2.4	0	0	0	0	0	0	0	0	0	0
Aspergillus flavus yellow mutant	0	0	0	0	0	0	0.854701	0	0	0	0	0
Aspergillus fumigatus	23.74101	0.8	1.941748	2.020202	0	0	0	0	0	0	0.990099	1.470588
Aspergillus kanagawaensis	0	0	0	0	0	0	0.854701	0	0	0	0	0
Aspergillus koningii	0	0	0	0	0	0	0	0	0	0	0	0
Aspergill	0.71	4	0	0	2.22	3.31	0.85	2.91	0	0	0	9.55

us niger	9424				2222	7536	4701	2621				8824
Aspergillus ochraceus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus petrakii	0	0	0.970874	0	0	0	0	0	0	0	0	0
Aspergillus raperi	0	0	0	1.010101	0	0	0	0	0	0	0	0
Aspergillus subalbidus	0	0	0	0	0	0	0	1.941748	0	0	0	0
Aspergillus sulphureus	0	0	0	0	0	0	0.854701	0	0	0	0	0
Aspergillus viridinutans	0	0	0	0	0	0.947867	0	0	0	0	0	0
Aspergillus sp 1	0	0	0	0	0	0	0	4.854369	0	0	0	0
Aspergillus sp 2	0	0	0.970874	0	0	0	0	0	0	0	0	0
Aspergillus sp 3	0	0	0	1.010101	0	0	0	0	0	0	0	0
Aspergillus sp 4	0.719424	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 5	0	0	0	0	0	0	0	0	0	0	0.49505	0
Aspergillus sp 6	0	0	0	0	0	0	0	0	0	0	0.49505	0
Aspergillus sp 7	0	0	0	0	0	11.37441	0	0	0	0	0	0
Aspergillus sp 8	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 9	0	0	0	0	0	0	1.709402	0	0	0	0	0
Aspergillus sp 10	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 11	0	0.8	0	0	0	0	0	0	0	0	0	0
Neosartorya quadricincta	0	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces stipitatus	0	0	0	0	0	0	0	0	4.545455	0	0	0
Paecilomyces victoriae	0	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium adametzii	0	0	0	0	0	2.843602	0	0	0	0	0	0

Penicillium aurantiogriseum var. *aurantiogriseum*	0	0	0.970874	0	0	0	0	0.970874	2.272727	0	0	0
Penicillium brevicompactum	0	0	0	0	0	0	0	0	0	0.952381	0	0
Penicillium capsulatum	0	0	0	0	0	0	0.854701	0	0	0	0	0
Penicillium chermesinum	0	0	0	0	0	0.947867	0	0	0	0	0.990099	0.735294
Penicillium chrysogenum	0	0	0.970874	0	0	0	0	0	0	0	0	0
Penicillium citrinum	0	0	0	0	0	0	0	7.76699	0	0	0	0
Penicillium crystallinum	4.316547	0	0	0	0	0	0	0	0	0	0	0
Penicillium cyaneum	0	0	0	0	1.333333	0	0	0	0	0	0	0
Penicillium granulatum	0	0	0	0	0	0	6.837607	0	0	0	0	0
Penicillium janczewskii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium janthinellum	0	0	5.825243	0	0	0	0	0	0	0	0	0
Penicillium javanicum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium lividum	0	0	0.970874	0	0	0	0	0	0	0	0	0
Penicillium miczynskii	0	0	1.941748	0	0	0	4.273504	0	0	0	0.49505	0
Penicillium novae-zeelandiae	0	0	0	0	0	0	0	0	0	0	0	0

Penicillium paxilli	0	0	0	1.010101	0	0	0	0	0	0	0	0
Penicillium restrictum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium roquefort i	0.719424	0	0	0	0	0	0	0	0	0	0	0
Penicillium roseopurpureum	0	0	0	0	0	0.947867	0	0	0	0	0	0
Penicillium simplicissimum	0	0	0	4.040404	0	2.843602	0	0	0	0	4.455446	3.676471
Penicillium spinulosum	0	0	0	0	0.888889	1.421801	0	0	0	0	0	0
Penicillium sublateritium	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium thomii var. *thomii*	0	0	0	0	0.444444	0	0	0	0	0.952381	7.425743	0.735294
Penicillium velutinum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium vinaceum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium waksmanii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 3	0	0	0	0	0.444444	0	0	0	0	0	0	0
Penicillium sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 5	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 6	0	0	0	0	0	0.947867	0	0	0	0	0	0
Penicillium sp 7	0	0	0	0	0	0	0	0	0	0.952381	0	0
Penicillium sp 8	0	0	0	0	0	0	0	0	0	0	0.990099	1.470588
Penicillium sp 9	0	0	0	0	0	0	0	0	0	0	0	0
Penicilliu	0	0	0	0	0	0	0	0	0	0	0	0

m sp 10												
Penicillium sp 11	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 12	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 13	0	0	0	0	0	0	0.854701	0	0	0	0.49505	0
Penicillium sp 14	0	0	0	0	0	0	0	0	0	0	0	0.735294
Penicillium sp 15	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 16	0	0	0	0	0	0	3.418803	1.941748	0	0	0	0
Penicillium sp 17	0	0	0	0	0	0	0	0	2.272727	2.857143	0	0
Penicillium sp 18	0	0	0	0	0	0	0	0	0	0.952381	0	0
Penicillium sp 19	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 20	0	0	0	0	0	0	1.709402	0	0	0	0	0
Penicillium sp 21	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 22	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces aculeatus	0	0	1.941748	0	0	0	0	0	0	0	0	0
Talaromyces atroroseus	0	0	0	0	0	0	0.854701	0	0	0	0	0
Talaromyces brunneus	0	0	0	0	0	0	0	0	0	0.952381	0	0
Talaromyces diversus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces duclauxii	0	0	0	0	0	0	4.273504	0.970874	4.545455	0	0	0
Talaromyces flavus	0	0	0	0	0	0	0	1.941748	0	0	0	0
Talaromyces funiculosus	0	0	2.912621	0	0	0	0	0	0	0	0	0
Talaromyces islandicus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces piceae	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces purpureogenus	0	0	0	0	0	0	0	0	0	0	0	0

Talaromyces variabilis	0	0	0	0	0	2.843602	0	0	0	0	3.960396	0
Talaromyces verruculosus	0	0	0	0	0	6.161137	0	0	0	0	0.49505	0
Talaromyces sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 3	0	0	0	0	0	0	1.709402	0	0	0	0	0
Talaromyces sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Oidiodendron sp 1	0	0	0	0	0	0	0	0	2.272727	0	0	0
Geotrichum candidum	0	0	0.970874	0	0	0	0	0	0	0	0	0
Colletotrichum aotearoa	0	0	0	0	0	0.473934	0	0	0	0	0	0
Colletotrichum sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum sp 2	0	0	0	0	0	0	0	0	0	1.904762	0	0
Furcasterigmium furcatum	0	0	0	0	0	0	0	0	0	0	0	0
Plectosphaerella cucumerina	0	0	0	0	0.444444	0.947867	0	0	0	0	0	0
Plectosphaerella sp 1	0	0	0	0	0	0	7.692308	0	0	0	0	0
Cordyceps farinosa	0	0	0	0	0	0	0.854701	0	0	0	0	0
Trichoderma asperelloides	0	0	0	3.030303	0	0	0	0	0	0	0	0
Trichoderma hamatum	0	0	0	0	0	2.843602	0	0	0	0	0	0
Trichoderma harzianum	0	0	1.941748	3.030303	0.444444	0	0	3.883495	15.90909	11.42857	13.36634	16.91176
Trichoderma spirale	0	0	0	0	0	0	0	0	0	0.952381	0	0
Trichoderma virens	0	0	0	0	0	0	0	0	0	0	0	0
Trichode	0	0	0	0	4.44	1.89	0	0.97	0	0.95	0	2.94

rma viride					4444	5735		0874		2381		1176
Trichoderma sp 1	0	0	0	2.020202	0	0	0	0	0	0	0	0.735294
Trichoderma sp 2	0	0	0	0	0	0	0	0	0	6.666667	0	0
Trichoderma sp 3	0	0	0	0	0	0	0	0	0	0	0	1.470588
Acremonium implicatum	0	0	0	0	0	0	3.418803	0	0	0	0	0
Acremonium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Acremonium sp 2	0	0	0	0	0	0	0	0	6.818182	0	0	0
Acremonium sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Acremonium sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix murorum	0	0	0	0	0	0	0	0	0	0	9.90099	0
Gliomastix roseogrisea	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix sp 1	0	0	0	0	0	0	0	0	0	0	0	0.735294
Sarocladium gamsii	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium hominis	0	0	0	0	0	0	0	0	0	2.857143	0	0
Sarocladium kiliense	11.51079	0	0	0	0	0	0	0	2.272727	0.952381	0	0
Sarocladium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Cosmospora butyri	0	0	0	0	0	0	0	0.970874	0	0	0	0
Fusarium oxysporum	0	9.6	0	0	0	0	0	0	0	0	0	0
Fusarium tricinctum	0	0	0	0	0	0	2.564103	0	0	0	0	0
Fusarium verticillioides	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium sp 1	0	0	0	0	0	0	5.128205	0	0	0	0	0
Fusarium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Mariannaea sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Neocosm	9.35	0	0	0	0	0	0	3.88	0	0	0	0

ospora solani	2518							3495				
Purpureocillium lilacinum	2.877698	0	2.912621	4.040404	0	1.421801	0.854701	5.825243	6.818182	0	28.21782	8.088235
Purpureocillium lilacinum natural mutant	0	0	1.941748	0	0	0	0	0	0	0	0	0
Cephalotrichum asperulum	0	0	0	0	0	0	0.854701	1.941748	0	0	0	0
Microascus atrogriseus	0	0	0	0	0	0	0	0	0	0	0	0
Microascus sp 1	0	0	0	0	0	0	0	0	0	0.952381	0	0
Scedosporium apiospermum	0	0	0	0	0	0	0	0.970874	0	0	0	0
Scedosporium sp 1	0	0	0	0	0	0	0	0	0	0.952381	0	0
Scopulariopsis asperula	0	0	0	0	0	0.947867	0	0	0	0	0	0
Scopulariopsis brevicaulis	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis candida	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis sp 1	0	0	0	0	0	0	0	0	0	0.952381	0	0
Wardomyces inflatus	0	0	0	0	0	0	0	0	0	0	0	0
Chloridium guttiferum	0	0	0	0	0	0	0	0	0	0	0	0
Chloridium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Chloridium sp 2	0	0	0	0	0	0	0	0	6.818182	0	0	0
Sirococcus tsugae	0	0	0	0	0	0	0	0.970874	0	0	0	0
Trichocladium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Trichocladium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Absidia cylindrospora	0	0	0	1.010101	0	0	0	0	0	0	0	0
Gongron	0	0	1.94	1.01	0	0	0	0	0	0	0	0

ella butleri			1748	0101								
Gongronella sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Gongronella sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Rhizomucor pusillus	0	0	0	0	0	0	0	0	0	0	0	0
Mucor bacilliformis	0	0	0	0	0	0	0	0	0	0	0	0
Mucor circinelloides	0	0	0	0	0	0.947867	0.854701	0.970874	2.272727	0.952381	0	3.676471
Mucor hiemalis f. corticola	0	0	0	0	0	0	0	0	0	0	0	0
Mucor hiemalis f. hiemalis	0	0	0	0	0	0	0	0	2.272727	0.952381	0	0
Mucor mucedo	0	0	0	0	0	0	0	0	0	0	0	0
NSF 1	0	0	0	0	0	0	0	0	0	0	0	0
NSF 2	0	0	0	0	0	0	0	0	0	0	0.49505	0
Unknown 1	0	0	0	1.010101	0	0	0	0	0	0	0	0
Unknown 2	0	0	0	0	0	0	0	0	0	0	0.49505	0
Unknown 3	0	0	0	0	0	0	0	0	0	0.952381	0	0
Unknown 4	0	0	0	0	0	0	0	0	0	0	0	0

Annexure 2. Table showing the Colony Forming Unit of species identified from Kollakal Thapovanam

Species	KSG											
	Pre 1		Mo 1		Po 1		Pre 2		Mo 2		P0 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Cladosporium cladosporioides	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria atra	0	0	0	0	0	0	0	0	0	1.639344	0	0
Alternaria tenuissima	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus brevipes	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus caesiellus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus carneus	0	1.219512	0	0	0	0	0	0	0	0	0	0
Aspergillus conicus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus coremiiformis	0	0	0	0	0	0	2.325581	0	0	0	0	0
Aspergillus duricaulis	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus flavus	0	1.219512	0	3.333333	0.306748	0	0	0	0	0	0	1.5625
Aspergillus flavus var. *columnaris*	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus flavus yellow mutant	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus fumigatus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus kanagawaensis	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus	0	0	0	0	0	0	0	0	0	0	0	0

koningii												
Aspergillus niger	0	0	3.333333	0	0	1.355014	0	0	0	0	0	2.34375
Aspergillus ochraceus	0	2.439024	0	0	0	0	0	0	0	0	0	0
Aspergillus petrakii	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus raperi	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus subalbidus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sulphureus	0	0	0	0	0	0	0	1.369863	0	0	0	0
Aspergillus viridinutans	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 5	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 6	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 7	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 8	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 9	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 10	1.123596	2.439024	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 11	0	0	0	0	0	0	0	0	0	0	0	0
Neosartorya quadricincta	5.617978	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces stipitatus	0	0	0	0	0	0	0	2.739726	0	0	0	0
Paecilomyces victoriae	0	0	0	0	0	0	0	0	3.703704	1.639344	0	0
Paecilomyces sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Penicilli	0	0	0	0	0	0	0	0	0	0	0	0

um adametzii												
Penicillium aurantiogriseum var. *aurantiogriseum*	0	0	0	0	0	0	0	0	0	1.639344	0	0
Penicillium brevicompactum	0	0	0	3.333333	0	0	0	0	0	1.639344	0	0
Penicillium capsulatum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium chermesinum	4.494382	0	0	0	0	0	0	0	0	0	0	0
Penicillium chrysogenum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium citrinum	0	0	3.333333	0	0.306748	0	0	6.849315	1.851852	0	1.538462	0
Penicillium crystallinum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium cyaneum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium granulatum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium janczewskii	0	0	0	0	0	0.813008	0	0	0	0	0	0
Penicillium janthinellum	0	0	0	6.666667	0	0	0	0	0	3.278689	0	0
Penicillium javanicum	0	0	0	0	0	0	0	0	0	1.639344	0	0
Penicillium lividum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium miczynskii	2.247191	0	0	0	0	0	0	0	0	0	0	0

Penicillium novae-zeelandiae	0	0	0	0	0	1.084011	0	0	0	0	0	0
Penicillium paxilli	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium restrictum	1.123596	0	0	0	0	0	0	0	0	0	0	0
Penicillium roquefortii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium roseopurpureum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium simplicissimum	0	0	6.666667	0	0	0.813008	0	2.739726	0	0	0	3.125
Penicillium spinulosum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sublateritium	0	2.439024	0	0	0	0	0	0	0	0	0	0
Penicillium thomii var. thomii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium velutinum	1.123596	0	0	0	0	0	0	0	0	0	0	0
Penicillium vinaceum	2.247191	0	0	0	0	0	0	0	0	0	0	0
Penicillium waksmanii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 1	3.370787	2.439024	0	0	0	0	0	0	0	0	0	0
Penicillium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 5	0	0	0	0	0	0	0	0	0	0	0	0
Penicilli	0	0	0	0	0	0	0	0	0	0	0	0

um sp 6												
Penicillium sp 7	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 8	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 9	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 10	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 11	0	0	0	0	0	0	0	0	0	1.639344	0	0
Penicillium sp 12	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 13	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 14	0	0	5	0	0.920245	0	58.13953	2.739726	0	0	0	4.6875
Penicillium sp 15	0	0	0	6.666667	0	0.271003	0	2.739726	1.851852	0	2.307692	0
Penicillium sp 16	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 17	0	0	0	0	0	0	0	2.739726	0	0	0	0
Penicillium sp 18	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 19	0	0	0	0	0	0	0	0	1.851852	4.918033	0	0
Penicillium sp 20	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 21	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 22	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces aculeatus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces atroroseus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces brunneus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces diversus	0	0	0	0	0	0	0	0	0	3.278689	0	0.78125
Talaromyces duclauxii	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces flavus	0	0	1.666667	0	0.613497	0	0	1.369863	0	0	0	0
Talaromyces funiculosus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces islandicu	0	24.39024	0	0	0	0	0	0	0	0	0	0

s												
Talaromyces piceae	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces purpureogenus	1.123596	0	0	0	0	0	0	0	0	0	2.307692	0
Talaromyces variabilis	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces verruculosus	0	0	0	6.666667	0	0.542005	0	0	0	0	0	0
Talaromyces sp 1	0	0	0	0	0	0	0	1.369863	0	0	0	0
Talaromyces sp 2	0	0	0	0	0	0	0	0	1.851852	0	0	0
Talaromyces sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Oidiodendron sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Geotrichum candidum	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum aotearoa	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum sp 1	0	0	0	0	0	0	0	0	0	1.639344	0	0
Colletotrichum sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Furcasterigmium furcatum	0	0	0	0	0	0	0	0	0	1.639344	0	0
Plectosphaerella cucumerina	0	0	0	0	0	0	0	0	0	1.639344	0	0
Plectosphaerella sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Cordyceps farinosa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma asperelloides	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma hamatum	0	0	0	0	0	0	0	0	0	0	0	0
Trichode	0	12.1	1.66	6.66	1.22	0	4.65	6.84	12.9	3.27	1.53	2.34

rma harzianum		9512	6667	6667	6994		1163	9315	6296	8689	8462	375
Trichoderma spirale	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma virens	1.12 3596	0	0	0	0	0.54 2005	0	0	0	0	0	0
Trichoderma viride	2.24 7191	0	0	3.33 3333	0	0	0	0	0	3.27 8689	0	0
Trichoderma sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma sp 2	0	0	0	0	0	0	0	0	1.85 1852	4.91 8033	0	0
Trichoderma sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Acremonium implicatum	0	0	3.33 3333	0	0	0	2.32 5581	0	0	0	0	0.78 125
Acremonium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Acremonium sp 2	0	0	0	0	0	0	0	0	0	3.27 8689	0.76 9231	0
Acremonium sp 3	0	0	0	3.33 3333	0	0	0	0	1.85 1852	0	1.53 8462	0
Acremonium sp 4	0	0	0	0	0.61 3497	0	0	0	0	1.63 9344	0	0
Gliomastix murorum	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix roseogrisea	0	1.21 9512	0	0	0	0	0	0	0	0	0	0
Gliomastix sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium gamsii	0	0	0	0	0	0	0	1.36 9863	0	0	0	0
Sarocladium hominis	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium kiliense	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium sp 1	0	0	0	0	0	0	0	0	1.85 1852	0	0	0
Cosmospora butyri	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium oxysporum	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium	0	0	1.66 6667	0	0	0	0	0	3.70 3704	0	0.76 9231	0

tricinctum												
Fusarium verticillioides	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium sp 1	0	0	0	0	0.306748	0	0	0	0	0	0	0
Fusarium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Mariannaea sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Neocosmospora solani	0	0	0	0	0	0	0	0	0	0	0	0
Purpureocillium lilacinum	0	0	3.333333	0	0.920245	0	0	2.739726	7.407407	1.639344	0	1.5625
Purpureocillium lilacinum natural mutant	0	0	0	0	0	0	0	0	0	0	0	0
Cephalotrichum asperulum	0	0	0	0	0	0	0	0	0	0	0	0
Microascus atrogriseus	7.865169	0	0	0	0	0	0	0	0	0	0	0
Microascus sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Scedosporium apiospermum	0	0	0	0	0	0	0	0	0	0	0	0
Scedosporium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis asperula	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis brevicaulis	0	0	0	0	0	0	0	1.369863	0	0	0	0
Scopulariopsis candida	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Wardomyces inflatus	0	0	0	0	0	0	0	0	0	0	0	0
Chloridium guttiferum	0	0	0	0	0	0	0	0	0	0	0	0

Chloridium sp 1	0	0	0	0	0.306748	0	0	0	0	1.639344	0	0
Chloridium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Sirococcus tsugae	0	0	0	0	0	0	0	0	0	0	0	0
Trichocladium sp 1	0	0	0	0	0	0	0	0	7.407407	4.918033	0	1.5625
Trichocladium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Absidia cylindrospora	0	0	0	0	0	0	0	0	0	0	0	0
Gongronella butleri	0	0	0	0	0	0	0	0	0	0	0	0
Gongronella sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Gongronella sp 2	0	0	1.666667	0	0	0.542005	0	2.739726	0	0	0	0
Rhizomucor pusillus	0	0	0	0	0	0	0	0	0	0	0	0
Mucor bacilliformis	0	0	0	0	0	0	0	0	0	0	0	0
Mucor circinelloides	0	0	6.666667	0	0.306748	0	0	21.91781	11.11111	4.918033	0	0
Mucor hiemalis f. *corticola*	0	0	0	0	0	0	0	0	0	0	1.538462	0
Mucor hiemalis f. *hiemalis*	1.123596	0	0	0	0	0	0	0	0	0	0	0.78125
Mucor mucedo	16.85393	13.41463	0	6.666667	0	0.813008	0	0	0	0	0	0
NSF 1	0	0	0	0	0	0	0	4.109589	0	0	0.769231	0
NSF 2	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 1	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 2	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 3	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 4	0	0	0	0	0	0	0	0	0	0	0	0

Annexure 3. Table showing the Colony Forming Unit of species identified from Poyilkavu

Species	PSG											
	Pre 1		Mo 1		Po 1		Pre 2		Mo 2		Po 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Cladosporium cladosporioides	0	0	0	0	0	0	3.448276	0	0	0	0	0
Alternaria atra	0	0	0	0	0	0	0	0	0	0	0	0
Alternaria tenuissima	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus brevipes	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus caesiellus	0	1.052632	0	0	0	0	0	0	0	0	0	0
Aspergillus carneus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus conicus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus coremiiformis	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus duricaulis	52.5974	38.94737	0	0	0	0	0	0	0	0	0	0
Aspergillus flavus	0	4.210526	0	0	0	1.102941	0	1.020408	0	0	0	2.34375
Aspergillus flavus var. *columnaris*	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus flavus yellow mutant	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus fumigatus	0	1.052632	0	0	0	0	0	0	0	0	0	0
Aspergillus kanagawaensis	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus	0	0	6.593407	1.639344	0	0	0	0	0	0	0	0

koningii												
Aspergillus niger	0	0	0	0	0	2.941176	0	1.020408	0	8.474576	0	0.78125
Aspergillus ochraceus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus petrakii	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus raperi	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus subalbidus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sulphureus	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus viridinutans	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 3	0	0	0	1.639344	0	0	0	0	0	0	0	0
Aspergillus sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 5	6.493506	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 6	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 7	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 8	0.649351	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 9	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 10	0	0	0	0	0	0	0	0	0	0	0	0
Aspergillus sp 11	0	0	0	0	0	0	0	0	0	0	0	0
Neosartorya quadricincta	0	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces stipitatus	0	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces victoriae	0	0	0	0	0	0	0	0	0	0	0	0
Paecilomyces sp 1	0	0	0	0	2.013423	0	0	0	0	0	0	0
Penicilli	0	0	0	0	0	0	0	0	0	0	0	0

um adametzii												
Penicillium aurantiogriseum var. *aurantiogriseum*	0	0	0	0	0	0	0	1.020408	0	0	0	0
Penicillium brevicompactum	0	0	0	0	0	0	3.448276	0	0	0	0	0
Penicillium capsulatum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium chermesinum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium chrysogenum	0	0	1.098901	0	0	0	0	0	0	0	0	0
Penicillium citrinum	0	0	0	0	0.33557	0	0	0	0	1.694915	0.645161	0.78125
Penicillium crystallinum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium cyaneum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium granulatum	0	0	0	0	0	0	0	1.020408	0	0	0	0
Penicillium janczewskii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium janthinellum	0	0	0	0	0	0	0	0	0.714286	3.389831	0	0
Penicillium javanicum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium lividum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium miczynskii	0	0	0	0	0	0	0	0	0	0	0	0

Penicillium novae-zeelandiae	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium paxilli	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium restrictum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium roquefortii	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium roseopurpureum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium simplicissimum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium spinulosum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sublateritium	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium thomii var. thomii	0	0	0	1.639344	0	0	0	0	0	0	0	0
Penicillium velutinum	0	0	2.197802	0	0	0	0	0	0	0	0	0
Penicillium vinaceum	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium waksmanii	0	0	0	0	0.671141	0	0	0	0	0	0	0
Penicillium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 2	0	0	0	0	0	0	0	0	1.428571	0	0	0
Penicillium sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 4	0	0	0	0	0	0	0	0	0.714286	0	0	0
Penicillium sp 5	0	0	0	0	0	0	0	0	0.714286	0	0	0
Penicilli	0	0	0	0	0	0	0	0	0	0	0	0

um sp 6												
Penicillium sp 7	0	0	0	0	0	0	0	0	1.428571	0	0	0
Penicillium sp 8	0	0	2.197802	3.278689	0	0	0	0	0	0	0	0
Penicillium sp 9	0	0	2.197802	3.278689	0	0	0	0	0	0	0	0
Penicillium sp 10	0	0	0	0	0	0	0	0	11.42857	0	0	0
Penicillium sp 11	0	0	0	0	0	0	24.13793	2.040816	0	0	0	0
Penicillium sp 12	0	0	1.098901	1.639344	0	0	0	0	0	0	0	0
Penicillium sp 13	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 14	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 15	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 16	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 17	0	0	0	0	0	0	0	0	0.714286	1.694915	0	0
Penicillium sp 18	0	0	0	0	0	0	0	1.020408	0	1.694915	0	0
Penicillium sp 19	0	0	0	0	0	0	0	0	0	6.779661	0	0
Penicillium sp 20	0	0	0	0	0	0	0	0	0	0	0	0
Penicillium sp 21	0	0	0	0	0	0	0	0	1.428571	0	0	0
Penicillium sp 22	0	0	0	0	0	0	0	0	0.714286	0	0	0
Talaromyces aculeatus	0	0	0	0	0.33557	0	0	0	0	0	0.645161	0
Talaromyces atroroseus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces brunneus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces diversus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces duclauxii	0	0	0	0	0	0	0	1.020408	0	1.694915	0	0
Talaromyces flavus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces funiculosus	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces islandicu	0	0	0	0	0	0	0	0	0	0	0	0

s												
Talaromyces piceae	0	0	3.296703	0	0	0	0	0	0	0	0	0
Talaromyces purpureogenus	0	0	0	0	0	0	0	3.061224	0	0	0	0
Talaromyces variabilis	0	0	1.098901	0	0	0	0	0	0	0	0	0
Talaromyces verruculosus	0	0	0	0	6.375839	0.367647	0	0	0	0	3.225806	1.5625
Talaromyces sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Talaromyces sp 4	0	0	0	0	0	0	0	0	0.714286	0	0	0
Oidiodendron sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Geotrichum candidum	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum aotearoa	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Colletotrichum sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Furcasterigmium furcatum	0	0	0	0	0	0	0	0	0	0	0	0
Plectosphaerella cucumerina	0	0	0	0	0	0	0	0	0	0	0	0
Plectosphaerella sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Cordyceps farinosa	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma asperelloides	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma hamatum	0	0	0	0	0	0	0	0	0	0	0	0
Trichode	0	0	0	0	0	0	10.3	30.6	0	0	1.29	2.34

rma harzianum							4483	1224			0323	375
Trichoderma spirale	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma virens	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma viride	0	0	0	0	0	0	3.448276	0	4.285714	13.55932	0	0
Trichoderma sp 1	0	0	2.197802	0	0	0	0	0	0	0	0	0
Trichoderma sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Trichoderma sp 3	0	0	0	0	0	0	0	0	0	0	0	0
Acremonium implicatum	0	0	0	0	0	0	0	0	1.428571	1.694915	0	0
Acremonium sp 1	0	0	1.098901	0	0	0	0	0	0	0	0	0
Acremonium sp 2	0	0	0	0	0	0	0	3.061224	0	0	0	0
Acremonium sp 3	0	0	1.098901	0	0	0	0	0	0	0	0	0
Acremonium sp 4	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix murorum	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix roseogrisea	0	0	0	0	0	0	0	0	0	0	0	0
Gliomastix sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium gamsii	0	0	0	0	0	0	0	0	0	0	0	0
Sarocladium hominis	0	0	0	0	0	0	0	0	0.714286	0	0	0
Sarocladium kiliense	0	0	0	0	0	0	0	1.020408	0	0	0	0
Sarocladium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Cosmospora butyri	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium oxysporum	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium	0	0	0	0	0	0	0	0	0.714286	0	0	0

tricinctum												
Fusarium verticillioides	0	0	0	0	2.348993	0	0	0	0	0	0	0
Fusarium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Fusarium sp 2	0	0	0	0	0	0	0	0	0.714286	0	0	0
Mariannaea sp 1	0	0	1.098901	0	0	0	0	0	0	0	0	0
Neocosmospora solani	0	0	0	0	0	0	0	0	0	0	0	0
Purpureocillium lilacinum	0.649351	0	7.692308	0	0	1.102941	0	0	40	3.389831	3.870968	5.46875
Purpureocillium lilacinum natural mutant	0	0	0	0	0	0	0	0	0	0	0	0
Cephalotrichum asperulum	0	0	0	0	0	0	0	0	0	0	0	0
Microascus atrogriseus	0	0	0	0	0	0	0	0	0	0	0	0
Microascus sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Scedosporium apiospermum	0	0	0	0	0	0	0	0	0	0	0	0
Scedosporium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis asperula	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis brevicaulis	0	0	0	0	0	0	0	0	0	0	0	0
Scopulariopsis candida	0	0	0	0	0	1.470588	0	0	0	0	0	0
Scopulariopsis sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Wardomyces inflatus	0	0	0	0	0	0	0	0	0.714286	0	0	0
Chloridium guttiferum	0	0	0	0	0	0	0	0	0	1.694915	0	0

Chloridium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Chloridium sp 2	0	0	0	0	0	0	0	0	0	0	0	0
Sirococcus tsugae	0	0	0	0	0	0	0	0	0	0	0	0
Trichocladium sp 1	0	0	0	0	0	0	0	0	0	0	0	0
Trichocladium sp 2	0	0	0	0	0	0	0	0	0.714286	0	0	0
Absidia cylindrospora	0	0	0	0	0	0	0	0	0	0	0	0
Gongronella butleri	0	0	2.197802	0	0	0.367647	0	0	0	0	0	0
Gongronella sp 1	0	0	0	0	1.006711	0.735294	0	0	0	0	1.290323	0
Gongronella sp 2	0	0	8.791209	8.196721	0	0	0	0	0	0	0	0
Rhizomucor pusillus	0	0	0	0	1.006711	0	0	0	0	3.389831	0	0
Mucor bacilliformis	0	0	0	0	1.006711	0	0	0	0	0	0	0
Mucor circinelloides	0	0	4.395604	3.278689	0	0	51.72414	16.32653	0.714286	0	0	0
Mucor hiemalis f. *corticola*	0	0	0	0	0	0	0	2.040816	0	0	0	0
Mucor hiemalis f. *hiemalis*	0	0	0	0	0	0	0	1.020408	0.714286	0	0	0
Mucor mucedo	0	0	0	0	0	0	0	0	0	0	0	0
NSF 1	0	0	0	0	0	0	0	0	0	0	0	0
NSF 2	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 1	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 2	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 3	0	0	0	0	0	0	0	0	0	0	0	0
Unknown 4	0	0	0	0	0	0	0	0	0	1.694915	0	0

Annexure 4. Table showing physicochemical parameters studied in each season of three sacred groves

Temp	Iringole Kavu	Kollakal Thapovanam	Poyilkavu
Pre 1	27.12±0.25	28.87±0.25	28±0
Pre 2	26.37±0.48	27.52±0.41	28±0
Mo 1	25.62±0.48	26.05±0.33	26±0
Mo 2	25.25±0.5	24.87±0.25	26.05±0.33
Po 1	20±0.4	22.37±0.48	21.37±0.48
Po 2	26.37±1.1	26.37±0.48	24.87±0.25
pH			
Pre 1	5±0.15	5.44±0.35	5.55±0.32
Pre 2	5.09±0.34	4.77±0.33	4.63±0.3
Mo 1	4.86±0.49	5.47±0.2	5.69±0.49
Mo 2	5.5±0.63	5.65±0.37	4.88±0.39
Po 1	4.92±0.38	5.69±0.75	4.63±0.73
Po 2	5.86±0.25	4.96±0.3	4.35±0.92
MC			
Pre 1	7.75±1.84	1.72±0.21	2.75±0.77
Pre 2	14.2±4.68	6.6±0.81	6.75±0.93
Mo 1	23.35±8.69	16.35±6.85	17.77±5.61
Mo 2	18.25±2.8	12.77±5.99	12.7±3.75
Po 1	10.15±1.25	2.45±0.62	5.85±2.39
Po 2	20.52±3.54	16.35±6.85	14.15±3.14
OC			
Pre 1	1.68±0.58	0.35±0.23	1.42±0.89
Pre 2	1.29±0.63	0.75±0.31	1.35±0.45
Mo 1	1.45±0.86	1.87±0.86	1.55±0.53
Mo 2	2.32±0.6	0.59±0.44	1.2±0.26
Po 1	1.99±0.62	0.73±0.17	1.37±1.25
Po 2	1.65±0.45	0.81±0.17	1.50±0.88
EC			
Pre 1	0.02±0.01	0.02±0.015	0.01±0.006
Pre 2	0.02±0.006	0.01±0.006	0.02±0.005
Mo 1	0.10±0.11	0.08±0.05	0.03±0.031
Mo 2	0.01±0.006	0.02±0.005	0.02±0
Po 1	0.02±0.005	0.01±0.005	0.01±0.008
Po 2	0.10±0.043	0.05±0.043	0.44±0.19
WHC			
Pre 1	29.51±4.48	25.99±6.56	34.61±3.11

Pre 2	36.57±3.42	28.57±2.75	16.99±19.6
Mo 1	33.69±5.62	26.84±11.5	37.84±1.89
Mo 2	30.83±6.83	23.49±5.29	22.32±3.63
Po 1	39.21±10.2	23.37±9.91	28.75±5.67
Po 2	52.29±2.12	29.35±1.31	46.11±3.31
Avail. N			
Pre 1	291.2±71.42	212.8±87.23	271.6±66.81
Pre 2	370.05±99.03	319.87±139.12	413.95±196.21
Mo 1	323.01±80.89	200.70±44.64	200.70±20.48
Mo 2	310.46±18.81	291.65±12.01	432.77±202.14
Po 1	204.4±37.00	182±14.09	268.77±97.15
Po 2	220.98±27.30	207.43±44.72	257±52.42
Avail. P			
Pre 1	21.25±8.22	57±20.35	55.5±35.98
Pre 2	13.44±2.41	52.36±17.14	33.04±12.62
Mo 1	14.84±4.32	67.2±24.62	51.8±21.21
Mo 2	14.56±4.08	35.28±16.77	24.64±9.28
Po 1	17.5±1.73	41±11.46	50.75±29.20
Po 2	19.405±3.83	47.25±16.59	51.8±29.75
Avail. K			
Pre 1	159.62±54.48	58.55±13.89	100.9±70.09
Pre 2	144.17±37.51	68.48±13.88	124.12±16.91
Mo 1	176.87±46.79	57.90±28.39	113.12±31.09
Mo 2	192.55±74.56	49.28±10.62	65.21±12.85
Po 1	145.25±46.59	69.32±16.04	100.12±57.14
Po 2	133.23±16.79	55.18±13.10	107.92±48.32
Ex. Ca			
Pre 1	1.60±1.85	2.49±1.26	6.43±2.59
Pre 2	1.54±0.41	0.58±0.24	1.12±0.59
Mo 1	0.94±0.22	0.37±0.11	0.53±0.12
Mo 2	1.84±1.22	0.81±0.51	0.93±0.48
Po 1	3.42±1.25	1.72±0.23	1.24±0.45
Po 2	2.02±1.12	1.11±0.24	0.92±0.29
Ex. Na			
Pre 1	3.39±0.6	4.09±0.09	4.54±0.68
Pre 2	0.08±0.005	0.07±0.005	0.14±0.11
Mo 1	0.2±0.03	0.18±0.02	0.20±0.02
Mo 2	0.09±0.01	0.08±0.005	0.10±0.005
Po 1	0.68±0.22	0.66±0.56	0.46±0.26
Po 2	0.38±0.49	0.14±0.05	0.26±0.06

Annexure 5. Table showing correlation matrix of parameters in Iringole Kavu

	Temp	pH	MC	OC	EC	WHC	Avail. N	Avail. P	Avail. K	Ex. Ca	Ex. Na
Temp		0.53792	0.61255	0.38182	0.54695	0.8585	0.22905	0.88327	0.82502	0.032285	0.65041
pH	0.31886		0.44193	0.58586	0.59383	0.18376	0.59213	0.75969	0.75103	0.95888	0.5995
MC	0.26447	0.39215		0.81383	0.077879	0.53592	0.75424	0.36608	0.58952	0.31924	0.12317
OC	-0.44064	0.28371	-0.12476		0.37213	0.73632	0.40937	0.87711	0.34758	0.30303	0.96346
EC	0.31218	0.27793	0.76255	-0.44869		0.25622	0.78747	0.85738	0.75493	0.40058	0.61425
WHC	-0.09462	0.62589	0.32035	-0.17766	0.55189		0.22598	0.65601	0.092639	0.53597	0.47775
Avail. N	0.57851	-0.27916	0.16535	-0.41812	-0.14265	-0.58158		0.17829	0.39622	0.078804	0.81759
Avail. P	0.07798	0.16161	-0.45375	0.08211	0.095372	0.23357	-0.63192		0.44539	0.62548	0.064167
Avail. K	0.11719	-0.16754	0.28105	0.46943	-0.16487	-0.73996	0.4288	-0.38943		0.42296	0.89876
Ex. Ca	-0.84947	0.027417	-0.49403	0.50847	-0.42524	0.32031	-0.76108	0.25522	-0.4072		0.96663
Ex. Na	0.23753	-0.27385	-0.69783	-0.02437	-0.26325	-0.36428	-0.12221	0.78535	-0.0676	-0.02225	

Annexure 6. Table showing correlation matrix of parameters in Kollakal Thapovanam

	Temp	pH	MC	OC	EC	WHC	Avail. N	Avail. P	Avail. K	Ex. Ca	Ex. Na
Temp		0.25712	0.96028	0.7873	0.78298	0.18501	0.57718	0.24107	0.74715	0.79	0.28514
pH	-0.55102		0.72955	0.94548	0.92165	0.011161	0.39603	0.65689	0.65302	0.55244	0.68273
MC	-0.02648	-0.18232		0.18647	0.09412	0.45647	0.94986	0.79343	0.18755	0.09594	0.17919
OC	-0.14277	0.036365	0.62293		0.025577	0.68097	0.60632	0.18784	0.96451	0.14818	0.34274
EC	0.14571	-0.05228	0.73779	0.86641		0.40998	0.40722	0.12369	0.52598	0.37334	0.68034
WHC	0.62452	-0.91245	0.38075	0.21605	0.41763		0.80101	0.31182	0.89777	0.56738	0.80562
Avail. N	0.29001	-0.42896	0.03344	-0.26894	-0.41986	0.13345		0.62161	0.90152	0.37613	0.57719
Avail. P	0.56658	-0.23296	0.1386	0.62144	0.69715	0.5006	-0.25799		0.79635	0.82163	0.60969
Avail. K	-0.17021	-0.23569	-0.62175	-0.02366	-0.32775	0.068261	-0.06575	0.13662		0.80462	0.99962
Ex. Ca	0.14094	0.30812	-0.73513	-0.66662	-0.44768	-0.29716	-0.44536	-0.11948	0.131		0.025622
Ex. Na	0.52473	0.21482	-0.63092	-0.47357	-0.21649	-0.13032	-0.29001	0.26652	0.000252	0.86629	

Annexure 7. Table showing correlation matrix of parameters in Poyilkavu

	Temp	pH	MC	OC	EC	WHC	Avail. N	Avail. P	Avail. K	Ex. Ca	Ex. Na
Temp		0.42469	0.86557	0.9711	0.7794	0.68737	0.51834	0.63078	0.74618	0.41063	0.43846
pH	0.40582		0.8897	0.58119	0.28697	0.79479	0.43813	0.55048	0.99736	0.36008	0.29453
MC	-0.08986	0.073669		0.52034	0.44304	0.4365	0.65688	0.85535	0.88452	0.12668	0.17304
OC	-0.01927	0.28709	0.33197		0.38072	0.06809	0.023651	0.047327	0.12121	0.96103	0.84698
EC	-0.14815	-0.52305	0.39127	0.44155		0.12202	0.59971	0.59475	0.75982	0.66871	0.69218
WHC	-0.21158	0.13768	0.39644	0.77862	0.69932		0.041919	0.069805	0.75465	0.83615	0.72589
Avail. N	0.33347	-0.39515	-0.23296	-0.87166	-0.2737	-0.82782		0.006631	0.44825	0.79288	0.66398
Avail. P	-0.25145	0.30957	-0.09674	0.81668	0.27728	0.77573	-0.93276		0.36075	0.43082	0.34733
Avail. K	0.17087	-0.00176	-0.07714	0.70037	0.16153	0.16506	-0.38718	0.45824		0.95639	0.98174
Ex. Ca	0.4171	0.45881	-0.69329	0.025983	-0.22464	0.10967	-0.13897	0.40094	-0.02908		3.68E-05
Ex. Na	0.39488	0.51615	-0.63779	0.10237	-0.20823	0.18485	-0.22796	0.46964	-0.01218	0.99505	

Annexure 8. Table showing season-wise ANOVA of temperature of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	134.625	5	26.925	74.56154	2.16E-11	2.772853
Within Groups	6.5	18	0.361111			
Total	141.125	23				

Annexure 9. Table showing season-wise ANOVA of temperature of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	100.5588	5	20.11175	139.9078	9.38E-14	2.772853
Within Groups	2.5875	18	0.14375			
Total	103.1463	23				

Annexure 10. Table showing season-wise ANOVA of temperature of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	120.7083	5	24.14167	360.6224	2.19E-17	2.772853
Within Groups	1.205	18	0.066944			
Total	121.9133	23				

Annexure 11. Table showing season-wise ANOVA of pH of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.0643	5	0.61286	3.682868	0.01802	2.772853
Within Groups	2.99535	18	0.166408			
Total	6.05965	23				

Annexure 12. Table showing season-wise ANOVA of pH of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.837288	5	0.567458	3.214475	0.030127	2.772853
Within Groups	3.177575	18	0.176532			
Total	6.014863	23				

Annexure 13. Table showing season-wise ANOVA of pH of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.915071	5	1.183014	3.588199	0.019954	2.772853
Within Groups	5.934525	18	0.329696			
Total	11.8496	23				

Annexure 14. Table showing season-wise ANOVA of moisture content of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	738.2421	5	147.6484	7.206512	0.000731	2.772853
Within Groups	368.7875	18	20.48819			
Total	1107.03	23				

Annexure 15. Table showing season-wise ANOVA of moisture content of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	892.16	5	178.432	8.186102	0.000353	2.772853
Within Groups	392.345	18	21.79694			
Total	1284.505	23				

Annexure 16. Table showing season-wise ANOVA of moisture content of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	661.2421	5	132.2484	12.67236	2.25E-05	2.772853
Within Groups	187.8475	18	10.43597			
Total	849.0896	23				

Annexure 17. Table showing season-wise ANOVA of organic carbon of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.747838	5	0.549568	1.35424	0.28729	2.772853
Within Groups	7.304625	18	0.405813			
Total	10.05246	23				

Annexure 18. Table showing season-wise ANOVA of organic carbon of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.536971	5	1.107394	5.817631	0.002286	2.772853
Within Groups	3.426325	18	0.190351			
Total	8.963296	23				

Annexure 19. Table showing season-wise ANOVA of organic carbon of Poyilkavu

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.305033	5	0.061007	0.098742	0.991127	2.772853
Within Groups	11.12115	18	0.617842			
Total	11.42618	23				

Annexure 20. Table showing season-wise ANOVA of electrical conductivity of Iringole Kavu

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.038288	5	0.007658	3.177752	0.031397	2.772853
Within Groups	0.043375	18	0.00241			
Total	0.081663	23				

Annexure 21. Table showing season-wise ANOVA of electrical conductivity of Kollakal Thapovanam

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.013121	5	0.002624	3.263212	0.028526	2.772853
Within Groups	0.014475	18	0.000804			
Total	0.027596	23				

Annexure 22. Table showing season-wise ANOVA of electrical conductivity of Poyilkavu

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.602088	5	0.120418	18.4981	1.57E-06	2.772853
Within Groups	0.117175	18	0.00651			
Total	0.719263	23				

Annexure 23. Table showing season-wise ANOVA of water holding capacity of Iringole Kavu

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1376.003	5	275.2005	7.516461	0.000577	2.772853
Within Groups	659.0348	18	36.61305			
Total	2035.037	23				

Annexure 24. Table showing season-wise ANOVA of water holding capacity of Kollakal Thapovanam

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	125.1361	5	25.02722	0.483439	0.784086	2.772853

Within Groups	931.8453	18	51.76918			
Total	1056.981	23				

Annexure 25. Table showing season-wise ANOVA of water holding capacity of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2258.452	5	451.6905	5.955379	0.002029	2.772853
Within Groups	1365.224	18	75.8458			
Total	3623.677	23				

Annexure 26. Table showing season-wise ANOVA of available nitrogen of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	79769.56	5	15953.91	4.001623	0.012874	2.772853
Within Groups	71763.48	18	3986.86			
Total	151533	23				

Annexure 27. Table showing season-wise ANOVA of available nitrogen of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62586.84	5	12517.37	2.399548	0.077995	2.772853
Within Groups	93897.93	18	5216.552			
Total	156484.8	23				

Annexure 28. Table showing season-wise ANOVA of available nitrogen of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	175070	5	35014	2.178671	0.102133	2.772853
Within Groups	289282.7	18	16071.26			
Total	464352.7	23				

Annexure 29. Table showing season-wise ANOVA of available phosphorus of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	188.884	5	37.77679	1.791502	0.165429	2.772853
Within Groups	379.5599	18	21.08666			
Total	568.4439	23				

Annexure 30. Table showing season-wise ANOVA of available phosphorus of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2622.486	5	524.4972	1.571847	0.218262	2.772853
Within Groups	6006.28	18	333.6822			
Total	8628.766	23				

Annexure 31. Table showing season-wise ANOVA of available phosphorus of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3169.388	5	633.8775	1.020115	0.434964	2.772853
Within Groups	11184.81	18	621.3786			
Total	14354.2	23				

Annexure 32. Table showing season-wise ANOVA of available potassium of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10070.61	5	2014.122	0.829	0.545606	2.772853
Within Groups	43732.44	18	2429.58			
Total	53803.05	23				

Annexure 33. Table showing season-wise ANOVA of available potassium of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1213.501	5	242.7001	0.839839	0.538822	2.772853
Within Groups	5201.716	18	288.9842			
Total	6415.216	23				

Annexure 34. Table showing season-wise ANOVA of available potassium of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8024.607	5	1604.921	0.807008	0.55955	2.772853
Within Groups	35797.16	18	1988.731			
Total	43821.77	23				

Annexure 35. Table showing season-wise ANOVA of exchangeable calcium of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.91022	5	2.782044	2.10202	0.112266	2.772853
Within Groups	23.82318	18	1.32351			
Total	37.7334	23				

Annexure 36. Table showing season-wise ANOVA of exchangeable calcium of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.638	5	2.5276	7.471966	0.000596	2.772853
Within Groups	6.089	18	0.338278			
Total	18.727	23				

Annexure 37. Table showing season-wise ANOVA of exchangeable calcium of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	101.4131	5	20.28261	16.01616	4.44E-06	2.772853
Within Groups	22.79493	18	1.266385			
Total	124.208	23				

Annexure 38. Table showing season-wise ANOVA of exchangeable sodium of Iringole Kavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33.31559	5	6.663118	60.51954	1.27E-10	2.772853
Within Groups	1.981775	18	0.110099			
Total	35.29736	23				

Annexure 39. Table showing season-wise ANOVA of exchangeable sodium of Kollakal Thapovanam

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	50.85213	5	10.17043	188.3315	6.91E-15	2.772853
Within Groups	0.97205	18	0.054003			
Total	51.82418	23				

Annexure 40. Table showing season-wise ANOVA of exchangeable sodium of Poyilkavu

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	62.25587	5	12.45117	136.3081	1.18E-13	2.772853
Within Groups	1.644225	18	0.091346			
Total	63.9001	23				

Annexure 41. Table showing axes and eigenvalues of season-wise CCA analysis of Iringole Kavu

Axis	Eigenvalue	%.
1	0.43244	40.44
2	0.23643	22.11
3	0.23546	22.02
4	0.11327	10.59
5	0.051864	4.85
6	4.36E-17	4.08E-15
7	2.70E-17	2.52E-15
8	1.91E-17	1.79E-15
9	1.66E-17	1.55E-15
10	1.35E-17	1.26E-15
11	1.32E-17	1.23E-15

Annexure 42. Table showing axes and eigenvalues of each fungus in season-wise CCA analysis of Iringole Kavu

score	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8	Axis 9	Axis 10	Axis 11
Alt	0.85213	2.85941	1.56891	3.14722	2.23993	2.20154	0.699494	5.49674	-1.61723	-7.85992	0.003196
Asp	1.03317	-0.57862	-0.14135	-0.27758	-0.61288	0.600817	0.295086	-0.61644	0.259587	0.042639	0.212527
Pae	-1.49386	1.06785	-3.40645	-0.10156	1.02991	-1.65034	-1.2019	-3.83614	-2.87324	0.493119	-3.22859
Pen	0.060021	1.09979	0.675679	-0.46489	-0.04882	0.474643	0.766205	-0.58132	-0.68265	0.127109	-0.45259
Tal	-0.20558	1.05003	0.598531	-0.37504	-1.7628	-0.86227	0.359425	0.360539	0.608389	-0.93194	-0.49486
Oid	-1.49386	1.06785	-3.40645	-0.10156	1.02991	0.911231	-0.61689	0.649877	-0.0471	-3.23027	5.63826
Geo	-0.51557	0.64844	2.26202	-7.35872	4.76537	-1.33577	-1.485	-3.86402	7.12434	-2.32451	-0.32729
Col	-1.18226	1.07622	-2.67061	-0.4095	-1.38079	-0.03289	-1.6647	-2.19471	1.20842	-5.20627	-0.74066
Ple	0.754062	2.59186	1.42387	2.3909	0.03154	-0.53178	0.447018	-0.90241	1.53582	2.03161	0.471187
Cor	0.85213	2.85941	1.56891	3.14722	2.23993	0.548743	-0.66923	0.19043	2.62768	-8.71041	1.14834

Tri	-1.08042	-0.24481	-0.32263	-0.0725	-0.24283	-1.15576	0.59043	-0.56066	0.105295	-0.1038	0.156522
Acr	-0.71038	1.66617	-1.74485	0.983422	1.43402	2.20774	-1.91178	-2.26029	1.73318	1.3926	-0.86866
Gli	-1.43728	-2.62273	1.55597	2.04335	-0.04855	0.734771	0.239874	0.030123	2.08367	0.694343	-1.73639
Sar	1.18848	-0.95462	-2.10424	-0.36583	0.972801	0.129518	0.180798	-0.08401	-0.26493	-1.94433	-1.27811
Cos	0.85213	2.85941	1.56891	3.14722	2.23993	-0.11407	-2.28676	2.44	1.66313	-3.37396	3.29688
Fus	1.82571	0.148736	-0.08828	1.1194	1.51972	-2.10701	0.215734	1.34348	-0.48619	0.544704	-1.26763
Neo	2.09128	-0.59068	-0.54033	0.566246	1.32326	-1.94752	2.70632	-1.06879	1.48175	0.0118	-0.01897
Pur	-0.8486	-1.06845	0.963129	0.39789	0.762226	0.64146	0.536218	-0.26838	-0.4334	-0.54591	-0.41887
Cep	0.85213	2.85941	1.56891	3.14722	2.23993	1.58221	3.73977	-3.77931	-0.8124	-3.87808	-0.94593
Mic	-1.49386	1.06785	-3.40645	-0.10156	1.02991	3.22297	-1.62534	4.42556	7.74161	-0.66924	-6.26386
Sce	-0.30959	1.97224	-0.89485	1.53845	1.64074	-1.27409	-1.92744	0.828008	4.11443	1.70283	-2.7683
Sco	-0.64283	1.09072	-1.39674	-0.9426	-5.5541	2.11943	3.30837	3.0086	3.27759	-1.66648	-7.79634
Chl	-1.49386	1.06785	-3.40645	-0.10156	1.02991	2.34482	4.33255	3.35115	-1.09659	1.89049	0.338369
Sir	0.85213	2.85941	1.56891	3.14722	2.23993	0.625824	-1.98789	2.31056	0.726041	-5.65137	2.99121
Abs	-0.51557	0.64844	2.26202	-7.35872	4.76537	-1.49048	1.73189	3.56134	6.23417	-0.38392	1.49627
Gon	-0.51557	0.64844	2.26202	-7.35872	4.76537	0.382584	0.471185	0.108052	1.41676	0.701968	-0.52839
Muc	-1.02038	0.272958	-0.99205	0.845594	-0.07606	0.680788	1.83974	-0.61811	2.0164	0.034986	2.26609
Pre 1 C	1.05755	-0.53225	-0.48053	-0.13722	0.156215	0.049623	0.188157	-0.17294	0.064501	-0.23132	-0.03379

Pre 1 P	1.22338	-0.40405	-0.12862	0.057692	-0.10106	-0.06962	-0.26396	0.242614	-0.09049	0.324506	0.047398
Pre 2 C	0.433527	1.08285	0.449164	0.51263	0.133845	-0.06232	-0.13355	0.113317	-0.00577	0.214074	-0.14502
Pre 2 P	0.295059	0.221071	0.278412	0.186484	0.097364	0.069413	0.148766	-0.12622	0.006433	-0.23846	0.161536
Mo 1 C	-0.13952	0.371559	0.693871	-0.94437	0.193967	0.100717	-0.04917	-0.05028	-0.01867	-0.07025	-0.13549
Mo 1 P	-0.31679	-0.09706	0.352797	-0.72576	0.305355	-0.12101	0.059074	0.060414	0.022428	0.084403	0.162788
Mo 2 C	-0.66538	0.300534	-0.93694	0.061896	0.216387	0.241256	0.038158	-0.03406	-0.16881	0.209126	0.16796
Mo 2 P	-0.6143	0.165456	-0.57218	-0.13121	-0.22775	-0.41877	-0.06623	0.059122	0.293027	-0.363	-0.29154
Po 1 C	-0.23102	0.196016	0.07908	-0.12703	-0.25191	-0.30883	0.034189	-0.20387	-0.20386	0.244403	0.193753
Po 1 P	0.171614	0.284116	0.168276	-0.23063	-0.72421	0.073944	-0.00819	0.048814	0.048811	-0.05852	-0.04639
Po 2 C	-0.79517	-0.94554	0.660813	0.450716	0.113216	0.128232	-0.07261	0.122393	0.055612	-0.06622	-0.27091
Po 2 P	-0.42679	-0.255	0.027484	-0.00845	-0.13183	-0.14547	0.082371	-0.13884	-0.06309	0.075119	0.307325
Temperature	0.216473	-0.28214	-0.02788	0.197373	0.720676	0.216982	-0.07457	0.243145	0.216903	-0.13472	-0.12557
pH	-0.5742	-0.38818	-0.18909	0.510113	0.050425	0.018386	0.001365	0.045568	0.154873	-0.12858	-0.08753
MC	-0.7552	0.009524	0.307631	-0.34531	0.45582	0.063175	0.061485	0.044535	0.169566	-0.14261	-0.07126
OC	-0.38178	-0.05549	-0.74486	0.001592	-0.44766	-0.21633	-0.03367	-0.04586	0.067836	-0.04863	-0.07021
EC	-0.40167	-0.3821	0.598041	-0.36437	0.38828	0.132559	0.046991	0.036558	0.017897	-0.00954	0.027308
WHC	-0.47037	-0.32205	0.483783	0.334525	-0.18164	0.032354	0.084112	-0.10901	-0.09392	0.04012	0.085438
Avail. N	0.25151	0.476793	-0.01663	-0.01445	0.62577	0.1275	-0.02627	0.154898	0.192986	-0.14316	-0.1168

Avail. P	0.389903	-0.76852	-0.11598	0.122645	-0.23888	0.021336	-0.07487	0.029155	-0.12902	0.137268	0.067504
Avail. K	-0.18262	0.2043	-0.54092	-0.50015	0.280888	-0.06591	-0.05686	0.11743	0.217264	-0.14114	-0.14909
Ex. Ca	-0.11352	0.025127	-0.12098	0.240647	-0.8243	-0.19841	0.045754	-0.22217	-0.21659	0.137586	0.118243
Ex. Na	0.800908	-0.48409	-0.29133	0.034955	-0.04941	0.046086	-0.11938	0.103546	-0.07956	0.113637	0.023566

Annexure 43. Table showing axes and eigenvalues of season-wise CCA analysis of Kollakal Thapovanam

Axis	Eigenvalue	%
1	0.27738	50.15
2	0.20389	36.87
3	0.055913	10.11
4	0.009406	1.701
5	0.006477	1.171
6	3.22E-17	5.83E-15
7	2.48E-17	4.48E-15
8	1.21E-17	2.19E-15
9	7.15E-18	1.29E-15
10	4.02E-18	7.28E-16
11	2.98E-18	5.39E-16

Annexure 44. Table showing axes and eigenvalues of each fungus in season-wise CCA analysis of Kollakal Thapovanam

score	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8	Axis 9	Axis 10	Axis 11
Alt	-2.67878	2.32771	-1.54754	-0.76045	-0.90027	-2.37642	1.17343	3.79693	-1.93721	7.82496	9.59739
Asp	0.930394	-0.17267	2.30422	-0.32941	2.21543	0.225745	0.095502	-0.56487	-1.50966	0.258055	0.608299
Neo	2.83845	2.0688	-1.45463	0.364123	1.15835	-3.67125	-1.24645	3.0009	0.642532	-0.80242	-0.2272
Pae	-1.81142	0.521952	-2.36186	-0.1292	0.262932	-0.27233	0.276845	-0.31918	-0.60956	-1.57115	0.336953
Pen	-0.05698	-1.12569	-0.28334	0.331051	0.285973	-0.27799	0.611081	0.101908	-0.42394	0.001583	0.121914
Tal	1.26302	0.978742	0.589476	0.014317	-0.11837	1.50624	1.58113	-0.02109	0.551896	-0.02525	0.338865
Col	-2.67878	2.32771	-1.54754	-0.76045	-0.90027	0.348828	7.33502	2.44211	-5.10309	-3.16185	-0.48891
Fur	-2.67878	2.32771	-1.54754	-0.76045	-0.90027	-0.46209	3.99868	1.67256	-0.80425	0.377159	4.9201
Ple	-2.49247	2.09767	-0.70964	1.09244	1.57921	-0.97523	4.34451	-1.67494	0.200548	10.4412	-7.65615
Tri	-0.39384	0.605709	0.064391	-0.42681	-0.51987	-0.18127	0.724747	0.217777	-0.67781	-0.48978	-0.32328

Acr	-0.97298	-0.01995	2.57351	1.0922	-1.13313	-2.15328	1.08762	-0.26284	0.999327	-0.48854	0.316543
Gli	2.83845	2.0688	-1.45463	0.364123	1.15835	1.01743	-3.5154	0.938423	-5.73553	4.94709	6.75265
Sar	-1.59074	0.062529	-2.56904	0.0314	0.558876	1.92054	1.80965	-1.72803	5.35074	-1.36349	3.631
Fus	-1.55443	0.954501	1.95253	1.69482	-3.06035	-0.14936	-1.07891	-2.23334	-1.89085	1.2923	-0.16033
Pur	-1.40924	0.433235	0.790171	-1.40084	0.441633	-0.29112	-0.73137	1.16486	1.72309	1.20199	0.035044
Mic	2.83845	2.0688	-1.45463	0.364123	1.15835	-4.39497	1.4222	-2.90334	0.775275	-0.00473	0.273821
Sco	-0.11987	-2.99966	-3.94995	1.10186	2.53143	2.34031	3.18117	-4.45795	3.67058	5.07419	-1.55087
Chl	-2.24965	1.80132	-0.35294	-9.14664	4.22261	-1.11732	0.86032	0.842967	-1.92504	-0.81581	-3.82427
Tric	-2.42725	2.01714	-0.4163	1.74113	2.44725	0.551569	-0.87458	-2.2519	-0.62772	-1.0856	0.525105
Gon	-0.0203	-2.13604	0.483245	-5.7747	-1.72325	-1.15139	0.1316	-5.00444	0.317904	-0.08691	2.32582
Muc	0.513221	0.23163	-0.59229	-0.06948	-0.94053	0.180926	-0.31038	-0.52971	-0.66992	0.240516	-0.22576
Pre 1 C	0.924872	0.35915	-0.59845	0.129695	0.06754	-0.91712	-0.244	-0.08376	0.080913	-0.0566	-0.14183
Pre 1 P	0.676162	0.47519	0.329914	-0.09681	-0.04456	0.747491	0.198873	0.06827	-0.06595	0.04613	0.115595
Pre 2 C	-0.07775	-0.9353	-0.07162	0.282257	0.247996	-0.17809	0.14418	0.260175	-0.11886	-0.06624	0.000458
Pre 2 P	0.017013	-0.25363	-0.40113	-0.28265	-0.24219	0.194837	-0.15774	-0.28465	0.130043	0.072474	-0.0005
Mo 1 C	-0.08996	-0.36177	0.413314	-0.13334	-0.15488	-0.12866	-0.1899	-0.14322	0.060142	0.131061	0.072504
Mo 1 P	0.134861	-0.10612	0.271661	0.083967	-0.10267	0.104995	0.154974	0.116874	-0.04908	-0.10695	-0.05917
Mo 2 C	-0.73815	0.519815	-0.08181	0.087253	-0.11488	0.149067	-0.40404	-0.20776	0.172473	-0.16463	-0.01095

Mo 2 P	-0.74717	0.429116	-0.10302	-0.10452	0.106597	-0.15849	0.429566	0.220887	-0.18337	0.175028	0.011641
Po 1 C	-0.34761	0.166535	0.509982	-0.66211	0.187991	-0.12143	0.033947	0.405505	0.297619	-0.00875	-0.27153
Po 1 P	0.290507	-0.54617	0.356068	-0.42353	0.267132	0.098958	-0.02767	-0.33047	-0.24255	0.007132	0.221287
Po 2 C	-0.04565	-0.00768	0.560562	0.354815	-0.51911	-0.07704	0.202323	-0.01412	0.182676	-0.07211	-0.0319
Po 2 P	-0.17643	-0.15132	0.478903	0.091663	0.645644	0.048182	-0.12653	0.00883	-0.11424	0.045098	0.01995
Temperature	0.54313	0.077181	-0.4491	0.613049	-0.21997	-0.04264	-0.03164	-0.0701	-0.02636	-0.01513	0.035629
pH	-0.10108	0.512903	0.130582	-0.48745	0.065292	-0.02106	-0.02152	0.046287	-0.01853	0.029451	-0.02948
MC	-0.51933	-0.0508	0.32877	0.486426	-0.20614	0.038073	0.043063	-0.0322	-0.00081	0.012794	0.065135
OC	-0.13151	-0.38876	0.373905	0.031785	-0.20286	0.03147	-0.01666	-0.02307	-0.00419	0.050616	0.048836
EC	0.053421	-0.14724	0.425496	0.328512	-0.23653	0.003909	-0.00393	-0.03912	0.006804	0.020683	0.049899
WHC	0.234892	-0.44566	0.058385	0.589573	-0.13409	0.007523	0.01715	-0.0569	0.025138	-0.02934	0.037685
Avail. N	-0.40405	-0.09403	-0.64425	0.265886	-0.11209	0.034387	0.000452	-0.02967	-0.05437	0.023199	0.044491
Avail. P	0.587042	-0.27994	0.018208	0.232859	-0.24078	-0.02491	-0.05613	-0.05436	-0.01023	0.024431	0.035341
Avail. K	0.334311	-0.63556	0.010958	-0.50913	0.179502	0.01353	-0.02875	0.024836	0.028182	0.002642	-0.04227
Ex. Ca	0.638189	0.437165	-0.05323	-0.21549	0.191729	-0.06963	-0.01738	0.027397	0.023554	-0.04796	-0.06985
Ex. Na	0.789916	0.453638	-0.27595	0.010874	0.013169	-0.08075	-0.04759	-0.0091	-0.00774	-0.0261	-0.03648

Annexure 45. Table showing axes and eigenvalues of season-wise CCA analysis of Poyilkavu

Axis	Eigenvalue	%
1	0.75734	44.32
2	0.40349	23.61
3	0.2865	16.77
4	0.21479	12.57
5	0.046587	2.726
6	8.57E-17	5.01E-15
7	3.03E-17	1.78E-15
8	1.55E-17	9.07E-16
9	2.74E-18	1.60E-16
10	2.29E-18	1.34E-16
11	1.37E-18	7.99E-17

Annexure 46. Table showing axes and eigenvalues of each fungus in season-wise CCA analysis of Poyilkavu

Score	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7	Axis 8	Axis 9	Axis 10	Axis 11
Cla	-0.94188	-1.81969	-0.32612	-0.46224	-0.2911	-1.53452	1.36479	0.978037	1.02484	3.53532	-9.53084
Asp	1.64993	-0.31465	0.08193	-0.04657	0.012419	0.107343	0.35315	-0.03441	0.157402	-0.07576	-0.10295
Pae	0.060965	2.3788	-6.84524	-4.12649	3.68071	-1.3852	-0.87169	-12.3545	-0.53395	-0.37785	-0.3712
Pen	-0.58	0.252066	0.39051	0.335626	0.962914	-0.07164	-1.08172	0.235005	-0.30102	0.34579	-0.03974
Tal	-0.29245	1.16566	-2.01045	-0.7178	-2.97334	0.240008	-1.28406	0.888507	0.947774	-0.00834	-0.18405
Tri	-0.75548	-0.62048	0.318232	-0.49734	-0.43441	-1.84189	1.10537	-0.07628	0.148847	-0.36251	0.387661
Acr	-0.57499	0.226173	0.369656	0.6702	1.23233	-0.15293	-0.125	0.222763	0.962582	-5.89659	-1.81154
Sar	-0.74387	-0.37651	0.658301	-0.76076	1.0269	-0.07738	0.879641	-0.88366	9.97812	5.70832	5.9963
Fus	-0.13643	2.11649	-3.47578	-3.01494	3.38916	-0.45109	3.06875	5.14449	-0.978	0.797143	0.516115
Mar	-0.22595	1.00224	-1.07008	4.88727	0.970318	-1.37591	4.94576	-1.29886	-5.56959	6.55935	2.89023

Pur	-0.36266	1.59438	1.25855	-0.41891	-0.70535	0.879159	1.09313	-0.58644	-0.33475	-0.05316	-0.24991
Sco	0.060965	2.3788	-6.84524	-4.12649	3.68071	0.126038	2.7745	3.17918	-1.8144	-1.90596	-0.52365
War	-0.461	1.68518	2.06462	-1.18722	2.90976	1.43886	-1.04427	1.29915	12.0538	-5.02944	3.66717
Chl	-0.461	1.68518	2.06462	-1.18722	2.90976	-0.68055	-0.18313	-2.04118	7.60604	3.13302	-6.10621
Tric	-0.461	1.68518	2.06462	-1.18722	2.90976	0.923082	-0.22163	0.996551	4.68132	-2.24483	2.23487
Gon	-0.20019	1.17237	-1.52235	3.72069	0.056501	-0.26107	1.44425	-0.16869	0.86552	-0.1791	-0.16633
Rhi	-0.34148	1.844	0.024456	-1.86025	3.08629	2.25384	2.62627	2.08248	1.00982	0.490271	0.273328
Muc	-0.85335	-1.43937	-0.43517	-0.01496	-0.06639	1.50346	0.611297	-0.24078	0.103574	-0.10156	0.007429
Pre 1 C	1.62829	-0.29412	0.094581	-0.05057	0.004701	0.003555	0.003409	-0.00254	-0.00227	0.000104	-0.00068
Pre 1 P	1.64993	-0.31465	0.08193	-0.04657	0.012419	-0.00474	-0.00455	0.003393	0.003025	-0.00014	0.000903
Pre 2 C	-0.76443	-0.8527	-0.08774	0.000324	0.167101	0.354936	-0.13263	-1.01E-05	-0.12703	0.194486	-0.18853
Pre 2 P	-0.65807	-0.63073	-0.04499	-0.23814	-0.25974	-0.52475	0.196082	1.49E-05	0.18781	-0.28754	0.278727
Mo 1 C	-0.15343	0.502995	-0.27897	0.885957	-0.14062	0.006609	0.091734	-0.01977	-0.02468	-0.06642	-0.01006
Mo 1 P	-0.19252	0.257748	-0.39835	1.36628	0.396804	-0.013	-0.18038	0.038882	0.048519	0.130597	0.019782
Mo 2 C	-0.4605	0.993274	0.794205	-0.26216	-0.03155	0.297717	0.087565	-0.10765	-0.13562	-0.00308	0.067454
Mo 2 P	-0.19831	0.196045	0.326204	-0.24083	0.385646	-0.42832	-0.12598	0.154869	0.19511	0.004435	-0.09704
Po 1 C	-0.27474	1.28642	-2.44975	-1.19281	-0.03423	-0.03197	-0.32725	-0.28712	0.155388	0.182564	0.057824
Po 1 P	0.746005	0.705455	-1.33098	-0.35594	0.451798	0.059695	0.610971	0.536045	-0.29011	-0.34085	-0.10796

Po 2 C	-0.37777	1.05389	-0.38407	-0.00223	-1.28618	0.031292	-0.18876	0.129419	0.163616	0.010541	-0.02561
Po 2 P	0.037045	0.624941	0.380108	-0.33592	-0.65734	-0.02584	0.155879	-0.10688	-0.13512	-0.0087	0.021146
Temperature	0.10223	-0.7976	0.752613	0.408174	-0.01261	-0.08794	-0.17452	-0.21236	0.182363	0.117771	0.142844
pH	0.481367	-0.26887	0.163402	0.665857	0.446268	0.033406	-0.11221	-0.07431	0.023185	0.138589	-0.00181
MC	-0.54546	0.40905	0.242051	0.58835	-0.22636	0.004334	-0.15621	-0.05631	0.087816	0.15032	-0.01588
OC	0.150655	0.048411	-0.17462	0.551433	-0.38981	0.100579	-0.06562	-0.04728	-0.01843	0.088453	0.030198
EC	-0.16389	0.359547	0.165734	-0.0524	-0.84929	0.046869	-0.07018	-0.04679	0.039766	0.054947	-0.01039
WHC	0.315214	0.440144	-0.03208	0.297888	-0.55309	0.127371	-0.08513	-0.02423	-0.02734	0.118141	-0.07023
Avail. N	-0.3923	-0.33877	0.400859	-0.39639	0.184269	-0.14443	0.00887	-0.03586	0.099508	-0.06639	0.062542
Avail. P	0.584517	0.181959	-0.41426	0.189593	-0.23848	0.144387	0.02765	0.034698	-0.11405	0.025615	-0.04769
Avail. K	-0.10152	-0.41861	-0.24951	0.292624	-0.23978	0.017908	0.021877	-0.04415	-0.00474	-0.03246	0.135774
Ex. Ca	0.885206	-0.40443	0.153435	-0.10023	0.090788	0.039175	-0.00772	-0.05197	-0.01967	0.020773	-0.00607
Ex. Na	0.906378	-0.36652	0.135189	-0.03604	0.085687	0.050728	-0.01613	-0.05192	-0.02397	0.034205	-0.01276

Annexure 47. Table showing site-wise Indicator Species analysis

Genus	ISG	KSG	PSG	Genus	ISG	KSG	PSG
Cla	0	0	8.333	**Cos**	8.333	0	0
Alt	2.856	5.478	0	**Fus**	10.47	7.809	2.288
Asp	41.05	6.432	31.1	**Mar**	0	0	8.333
Neo	0	8.333	0	**Neo**	16.67	0	0
Pae	2.587	13.8	1.146	**Pur**	33.09	6.164	25.4
Pen	20.3	49.09	19.91	**Cep**	16.67	0	0
Tal	19.02	40.94	15.16	**Mic**	0.9001	7.433	0
Oid	8.333	0	0	**Sce**	16.67	0	0
Geo	8.333	0	0	**Sco**	6.681	2.408	2.585
Col	9.867	3.4	0	**War**	0	0	8.333
Fur	0	8.333	0	**Chl**	5.432	3.101	1.35
Ple	21.18	1.274	0	**Sir**	8.333	0	0
Cor	8.333	0	0	**Tric**	0	23.78	0.4076
Tri	30.64	30.13	16.93	**Abs**	8.333	0	0
Acr	4.48	34.07	7.337	**Gon**	1.614	4.058	30.87
Gli	14.95	0.8572	0	**Rhi**	0	0	16.67
Sar	19.5	2.381	1.282	**Muc**	3.579	43.8	22.53

Annexure 48. Table showing season-wise Indicator Species analysis in Iringole Kavu

Genus	Pre 1		Pre 2		Mo 1		Mo 2		Po 1		Po 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Alt	0	0	100	0	0	0	0	0	0	0	0	0
Asp	21.48	23.89	4.03	10.68	3.052	3.969	5.358	0	1.746	12.66	3.89	9.244
Pae	0	0	0	0	0	0	100	0	0	0	0	0
Pen	6.215	0	22.15	13.18	13.18	6.233	5.61	8.228	3.84	12.28	0	9.075
Tal	0	0	20.37	8.678	14.46	0	13.54	2.838	0	26.83	13.28	0
Oid	0	0	0	0	0	0	100	0	0	0	0	0
Geo	0	0	0	0	100	0	0	0	0	0	0	0
Col	0	0	0	0	0	0	0	80.08	0	19.92	0	0
Ple	0	0	84.67	0	0	0	0	0	4.892	10.43	0	0
Cor	0	0	100	0	0	0	0	0	0	0	0	0
Tri	0	0	0	5.065	2.026	8.432	16.6	20.87	5.101	4.945	13.95	23.02
Acr	0	0	33.4	0	0	0	66.6	0	0	0	0	0
Gli	0	0	0	0	0	0	0	0	0	0	93.09	6.913
Sar	65.43	0	0	0	0	0	12.92	21.65	0	0	0	0
Cos	0	0	0	100	0	0	0	0	0	0	0	0
Fus	0	55.52	44.48	0	0	0	0	0	0	0	0	0
Neo	70.66	0	0	29.34	0	0	0	0	0	0	0	0
Pur	4.568	0	1.357	9.247	7.706	6.413	10.82	0	0	2.257	44.79	12.84
Cep	0	0	30.56	69.44	0	0	0	0	0	0	0	0
Mic	0	0	0	0	0	0	0	100	0	0	0	0
Sce	0	0	0	50.48	0	0	0	49.52	0	0	0	0
Sco	0	0	0	0	0	0	0	50.12	0	49.88	0	0
Chl	0	0	0	0	0	0	100	0	0	0	0	0
Sir	0	0	0	100	0	0	0	0	0	0	0	0
Abs	0	0	0	0	0	100	0	0	0	0	0	0
Gon	0	0	0	0	65.78	34.22	0	0	0	0	0	0
Muc	0	0	6.626	7.526	0	0	35.24	14.77	0	7.348	0	28.5

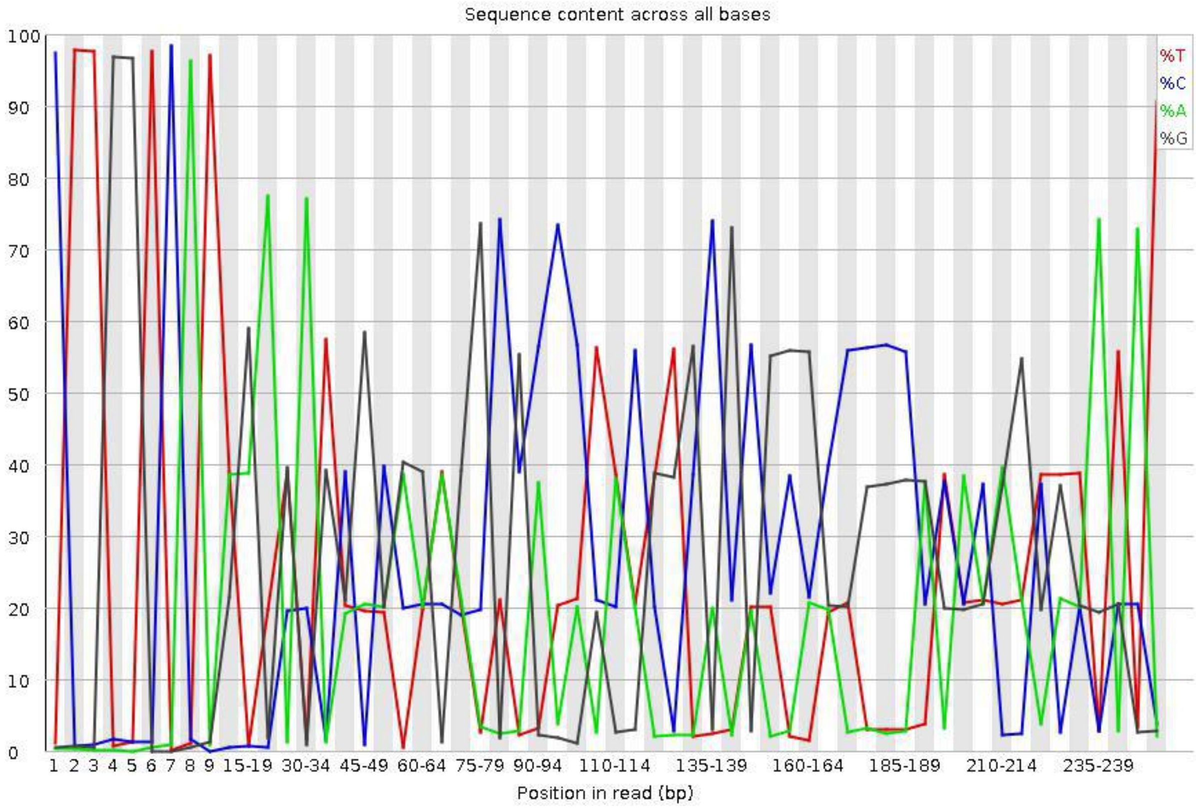
Annexure 49. Table showing season-wise Indicator Species analysis in Kollakal Thapovanam

Genus	Pre 1		Pre 2		Mo 1		Mo 2		Po 1		Po 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Alt	0	0	0	0	0	0	0	100	0	0	0	0
Asp	4.61	30.02	9.542	5.621	13.68	13.68	0	0	1.259	5.56	0	16.03
Neo	100	0	0	0	0	0	0	0	0	0	0	0
Pae	0	0	0	33.9	0	0	45.82	20.28	0	0	0	0
Pen	8.946	2.988	35.61	10.91	9.187	10.21	3.403	9.036	0.7515	1.826	2.356	4.785
Tal	2.445	53.07	0	5.961	3.626	14.5	4.029	7.133	1.335	1.179	5.021	1.7
Col	0	0	0	0	0	0	0	100	0	0	0	0
Fur	0	0	0	0	0	0	0	100	0	0	0	0
Ple	0	0	0	0	0	0	0	100	0	0	0	0
Tri	4.769	17.26	6.581	9.691	2.358	14.15	20.96	16.24	1.736	0.7669	2.177	3.316
Acr	0	0	11.95	0	17.13	17.13	9.514	25.27	3.152	0	11.86	4.014
Gli	0	100	0	0	0	0	0	0	0	0	0	0
Sar	0	0	0	42.52	0	0	57.48	0	0	0	0	0
Fus	0	0	0	0	25.85	4.758	57.45	0	0	0	11.93	0
Pur	0	0	0	15.56	18.94	0	42.08	9.313	5.228	0	0	8.877
Mic	100	0	0	0	0	0	0	0	0	0	0	0
Sco	0	0	0	100	0	0	0	0	0	0	0	0
Chl	0	0	0	0	0	0	0	84.24	15.76	0	0	0
Tric	0	0	0	0	0	0	53.34	35.41	0	0	0	11.25
Gon	0	0	0	55.37	33.68	0	0	0	0	10.95	0	0
Muc	20.88	15.58	0	25.45	7.742	7.742	12.9	5.711	0.3562	0.9441	1.787	0.9072

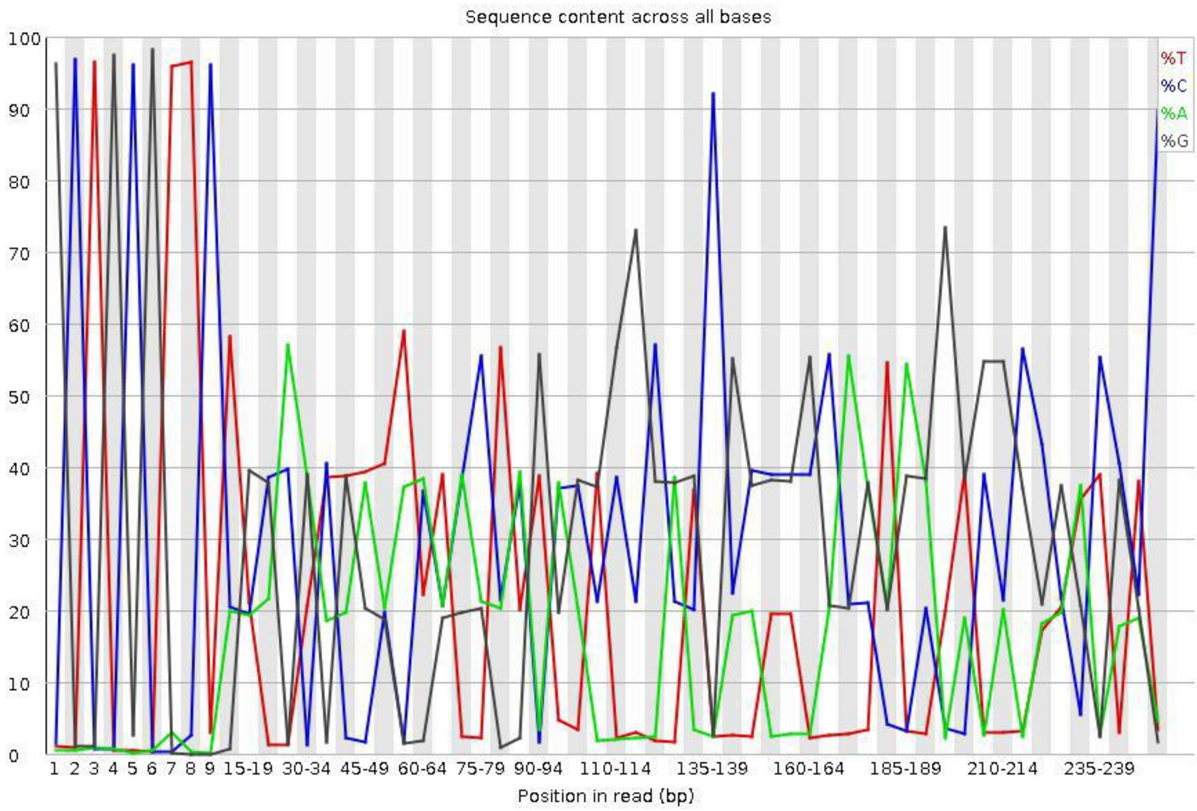
Annexure 50. Table showing season-wise Indicator Species analysis in Poyilkavu

Genus	Pre 1		Pre 2		Mo 1		Mo 2		Po 1		Po 2	
	C	P	C	P	C	P	C	P	C	P	C	P
Cla	0	0	100	0	0	0	0	0	0	0	0	0
Asp	45.07	34.15	0	1.54	4.974	2.473	0	6.393	0	3.051	0	2.357
Pae	0	0	0	0	0	0	0	0	100	0	0	0
Pen	0	0	31.25	5.779	9.957	11.14	21.84	17.28	1.14	0	0.7307	0.8849
Tal	0	0	0	17.44	18.79	0	3.053	7.244	28.68	1.571	16.54	6.678
Tri	0	0	20.26	44.96	3.228	0	6.295	19.92	0	0	1.895	3.443
Acr	0	0	0	36.52	26.22	0	17.04	20.22	0	0	0	0
Sar	0	0	0	58.82	0	0	41.18	0	0	0	0	0
Fus	0	0	0	0	0	0	37.82	0	62.18	0	0	0
Mar	0	0	0	0	100	0	0	0	0	0	0	0
Pur	1.044	0	0	0	12.37	0	64.34	5.452	0	1.774	6.226	8.796
Sco	0	0	0	0	0	0	0	0	0	100	0	0
War	0	0	0	0	0	0	100	0	0	0	0	0
Chl	0	0	0	0	0	0	0	100	0	0	0	0
Tric	0	0	0	0	0	0	100	0	0	0	0	0
Gon	0	0	0	0	48.65	36.29	0	0	4.457	4.883	5.713	0
Rhi	0	0	0	0	0	0	0	77.1	22.9	0	0	0
Muc	0	0	63.68	23.87	5.412	4.037	1.759	0	1.239	0	0	0

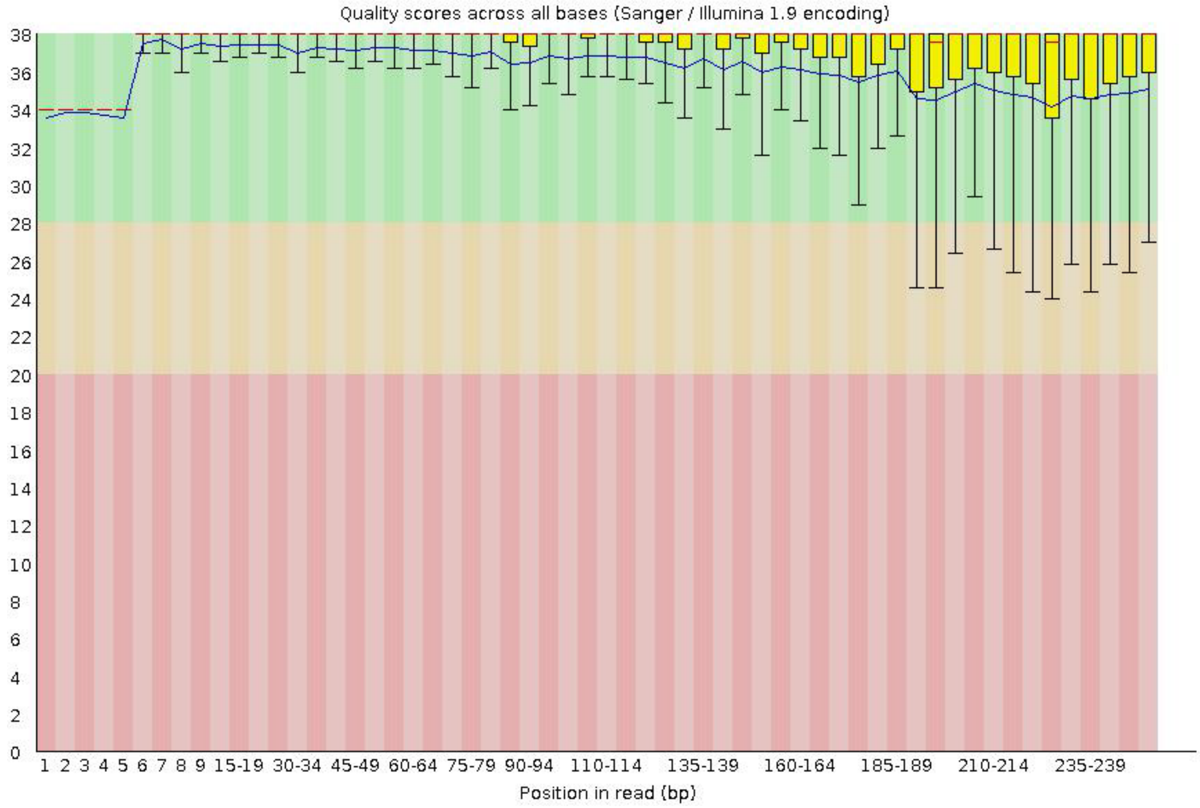
Annexure 51. Average base composition of R1 reads of Iringole Kavu



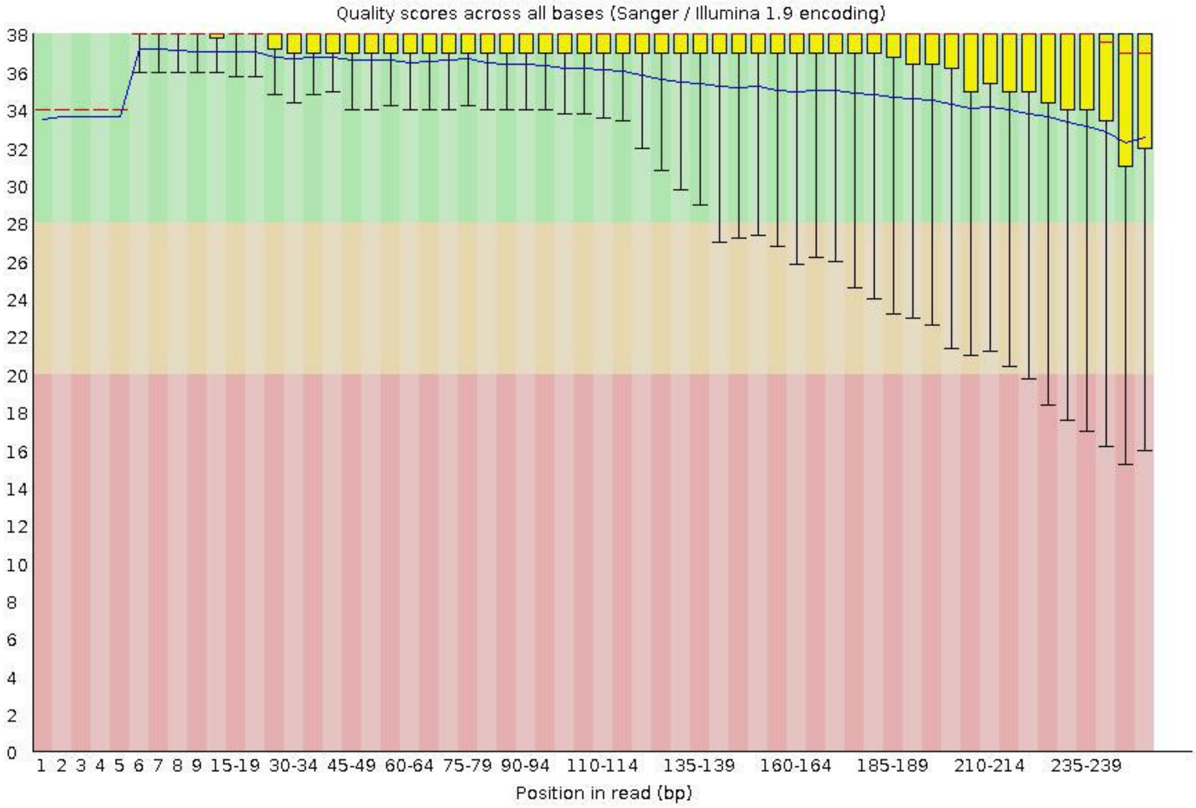
Annexure 52. Average base composition of R2 reads of Iringole Kavu



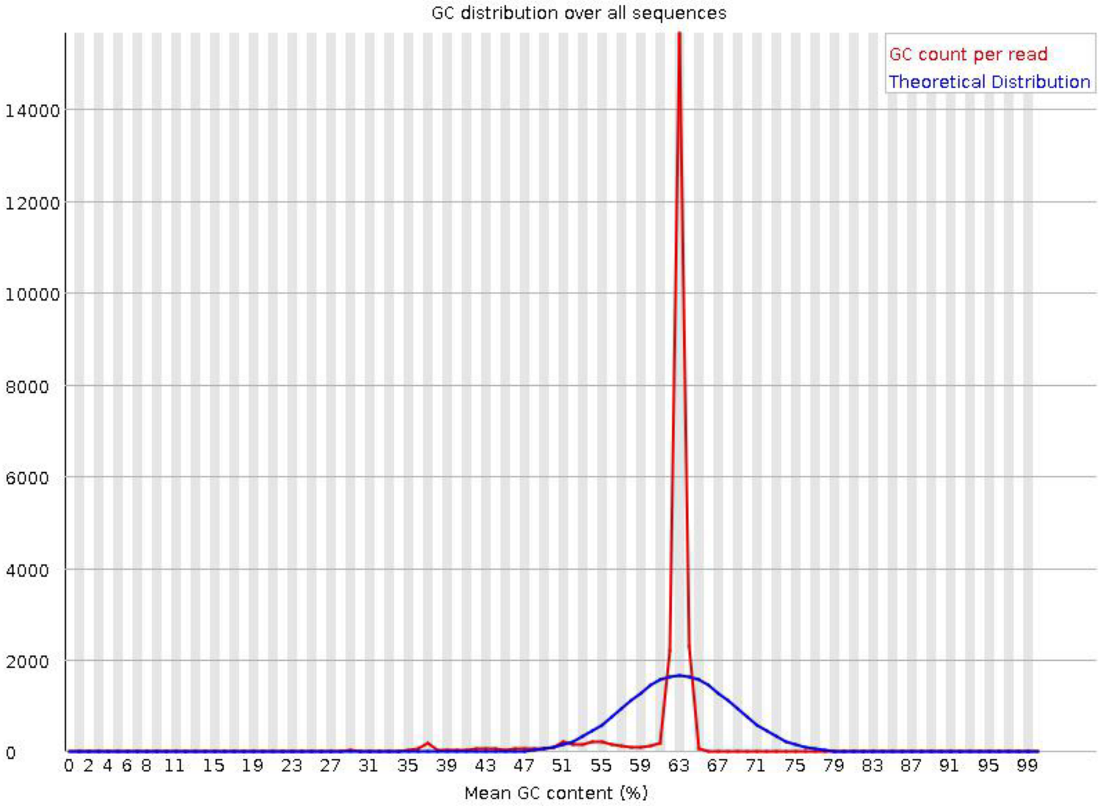
Annexure 53. Average base quality of R1 reads of Iringole Kavu



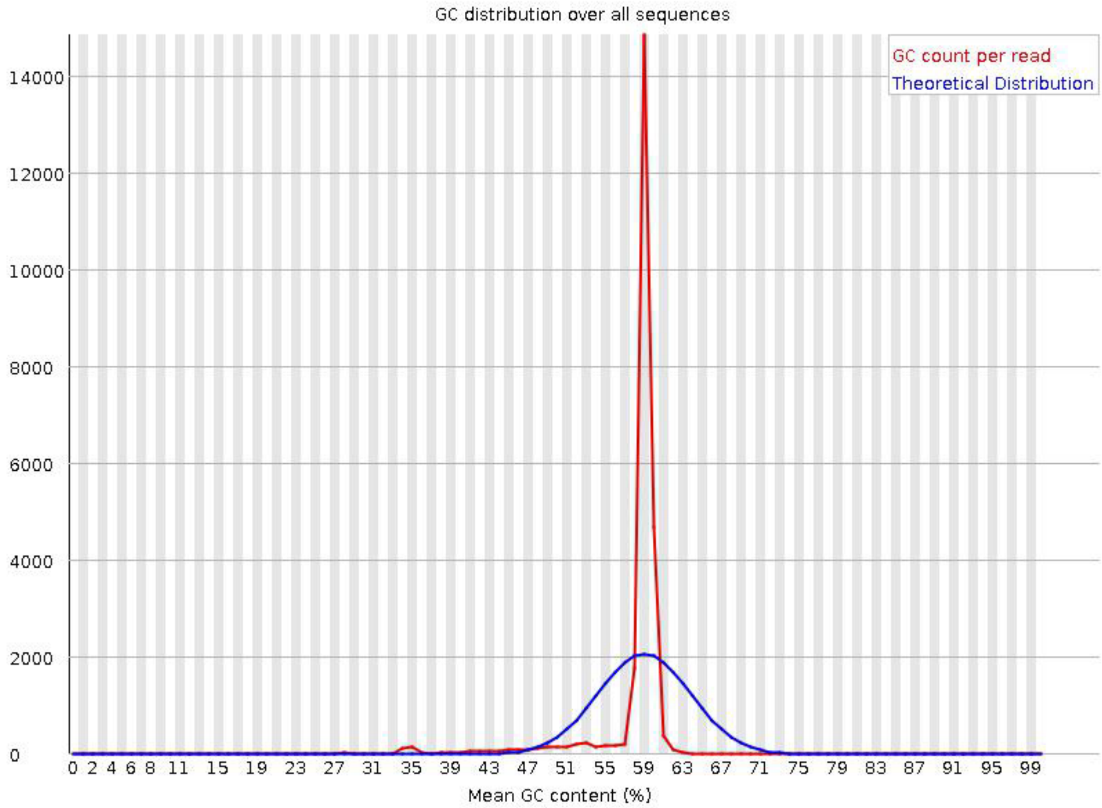
Annexure 54. Average base quality of R2 reads of Iringole Kavu



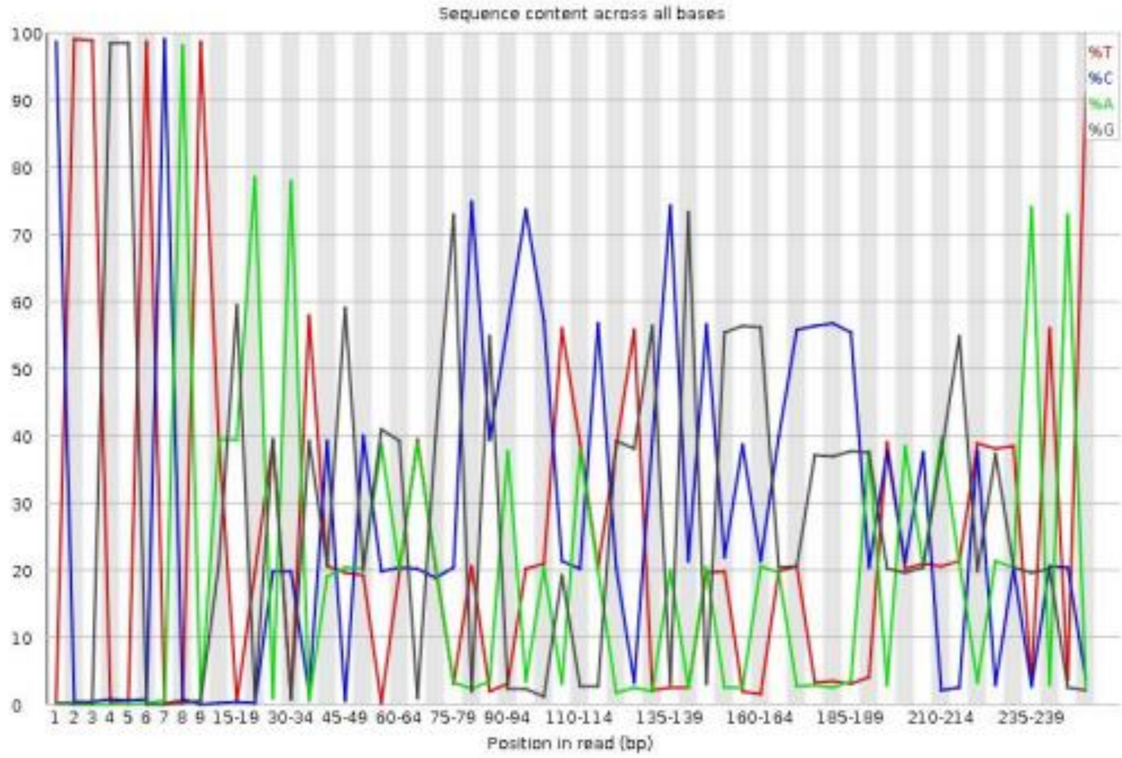
Annexure 55. GC distribution of R1 reads of Iringole Kavu



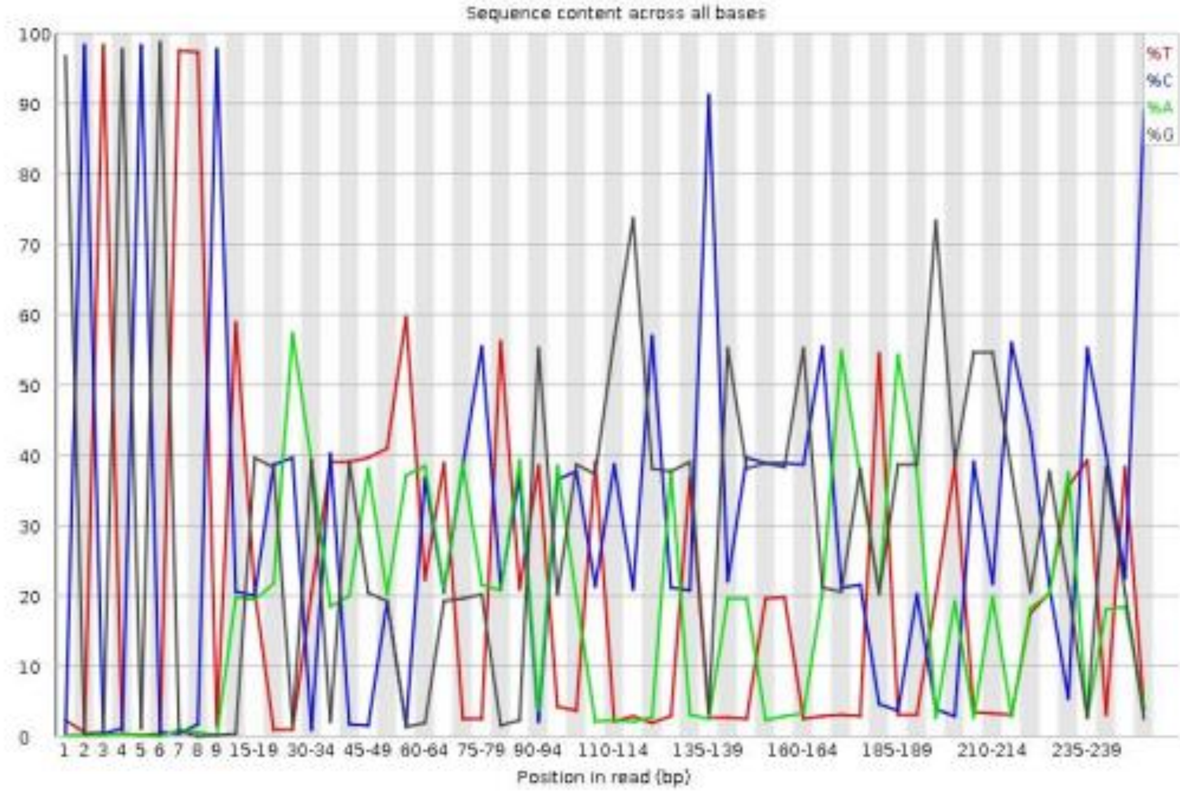
Annexure 56. GC distribution of R2 reads of Iringole Kavu



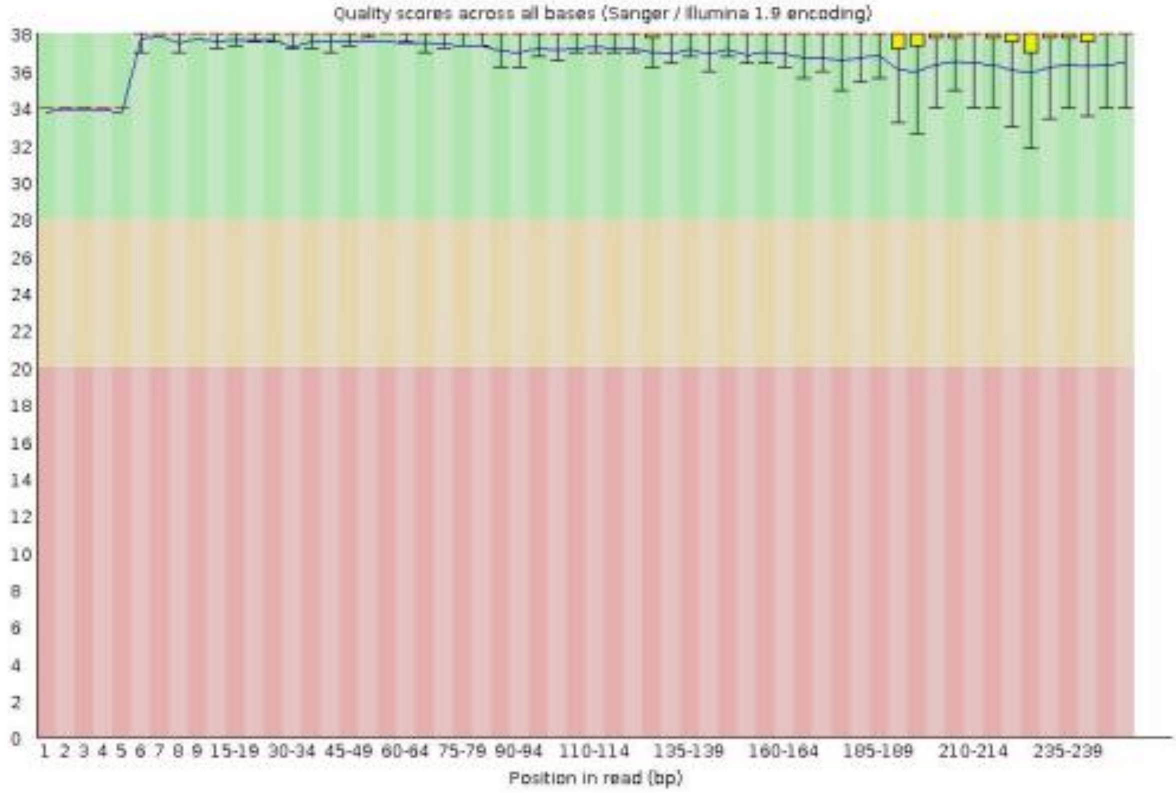
Annexure 57. Average base composition of R1 reads of Kollakal Thapovanam



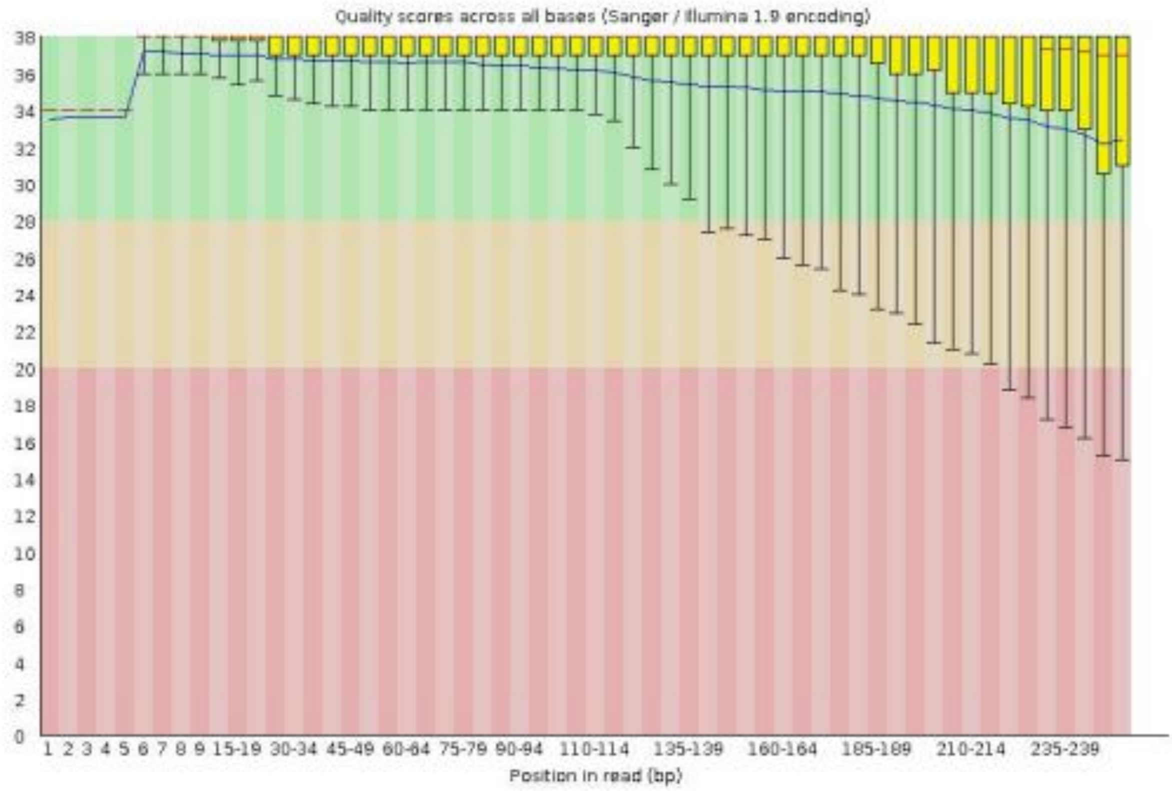
Annexure 58. Average base composition of R2 reads of Kollakal Thapovanam



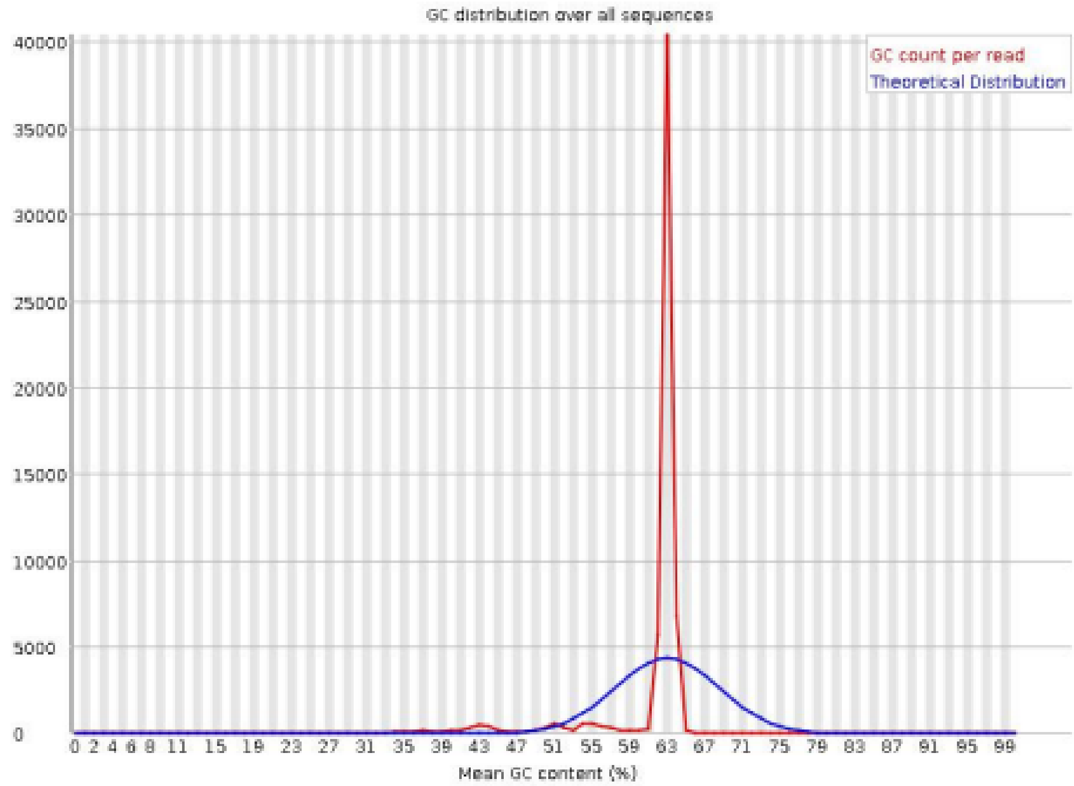
Annexure 59. Average base quality of R1 reads of Kollakal Thapovanam



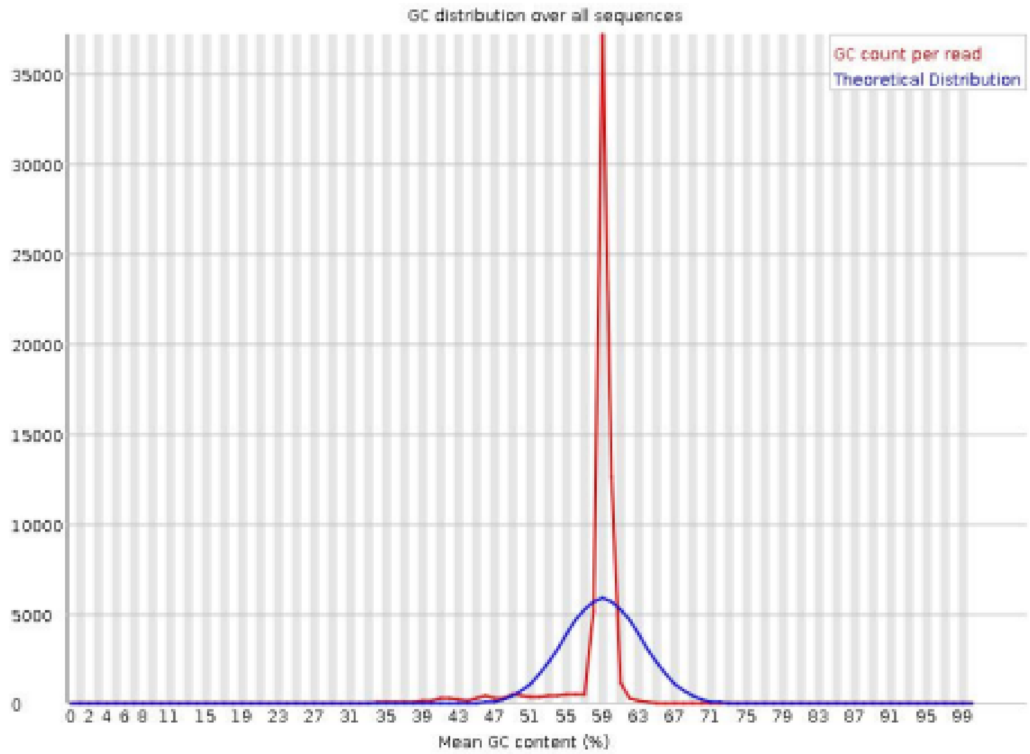
Annexure 60. Average base quality of R2 reads of Kollakal Thapovanam



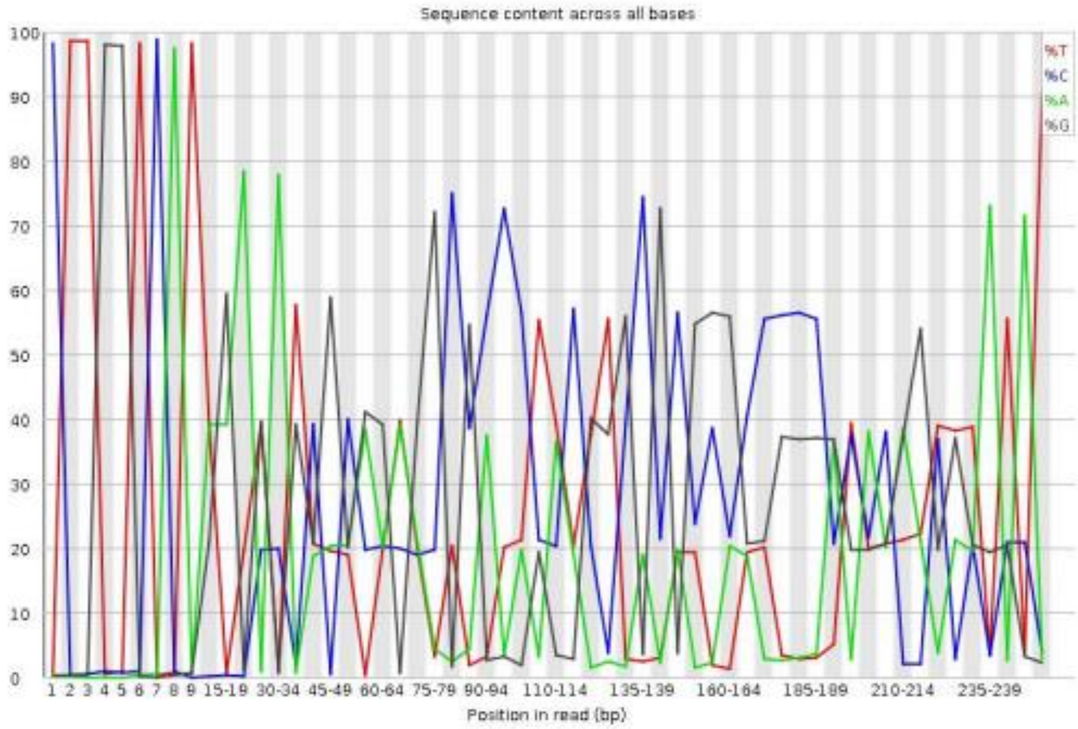
Annexure 61. GC distribution of R1 reads of Kollakal Thapovanam



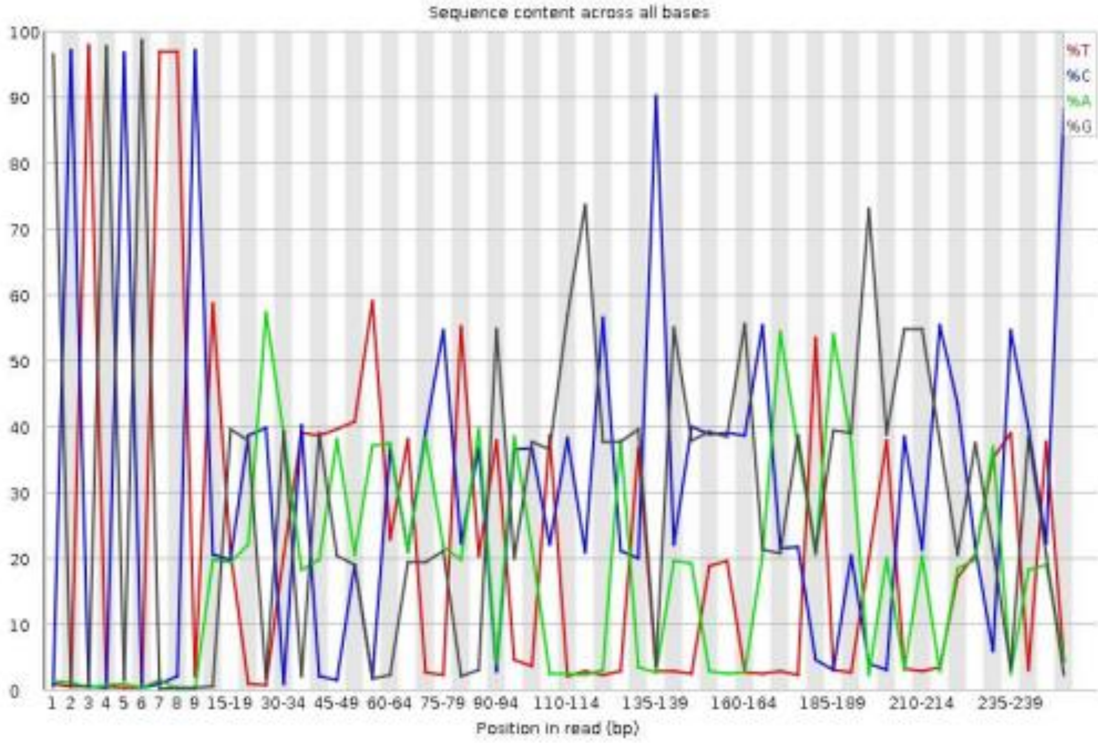
Annexure 62. GC distribution of R2 reads of Kollakal Thapovanam



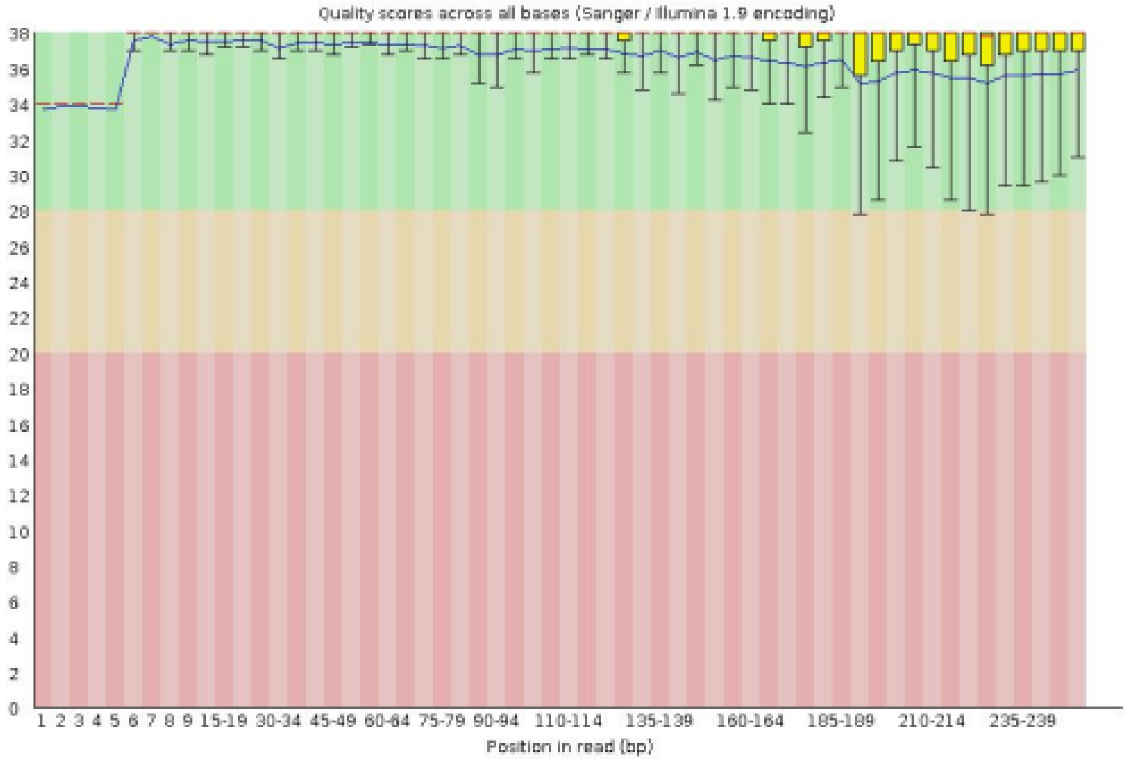
Annexure 63. Average base composition of R1 reads of Poyilkavu



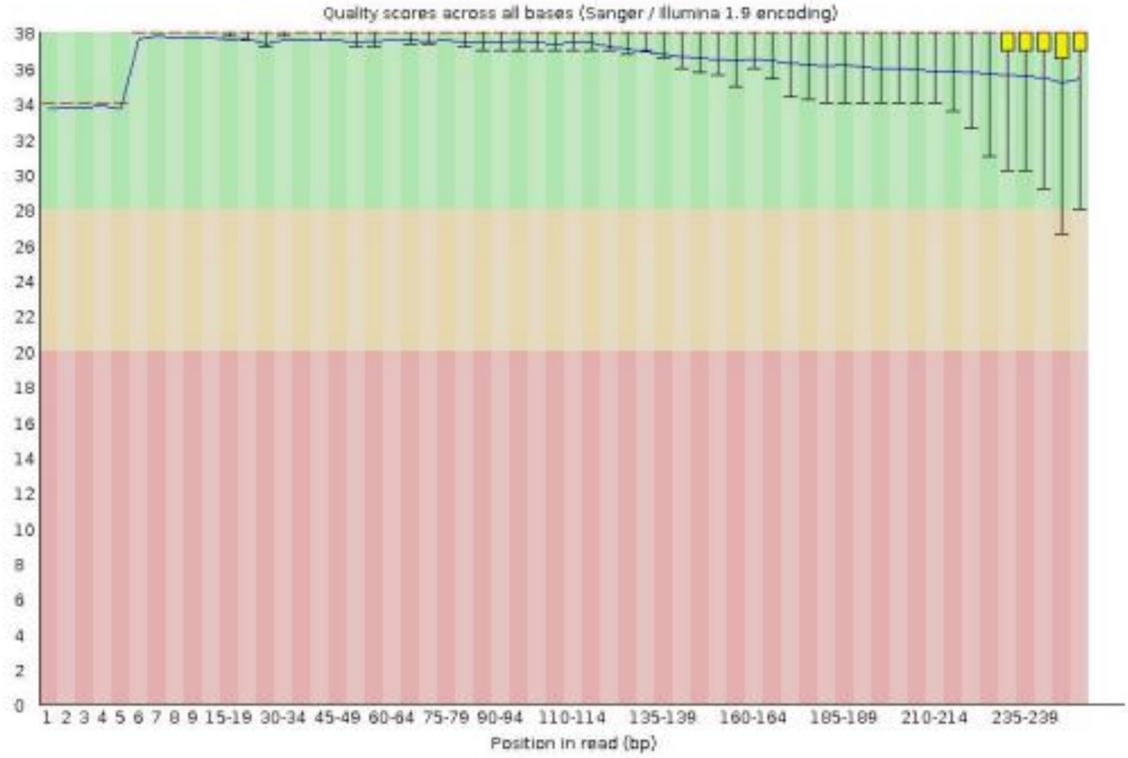
Annexure 64. Average base composition of R2 reads of Poyilkavu



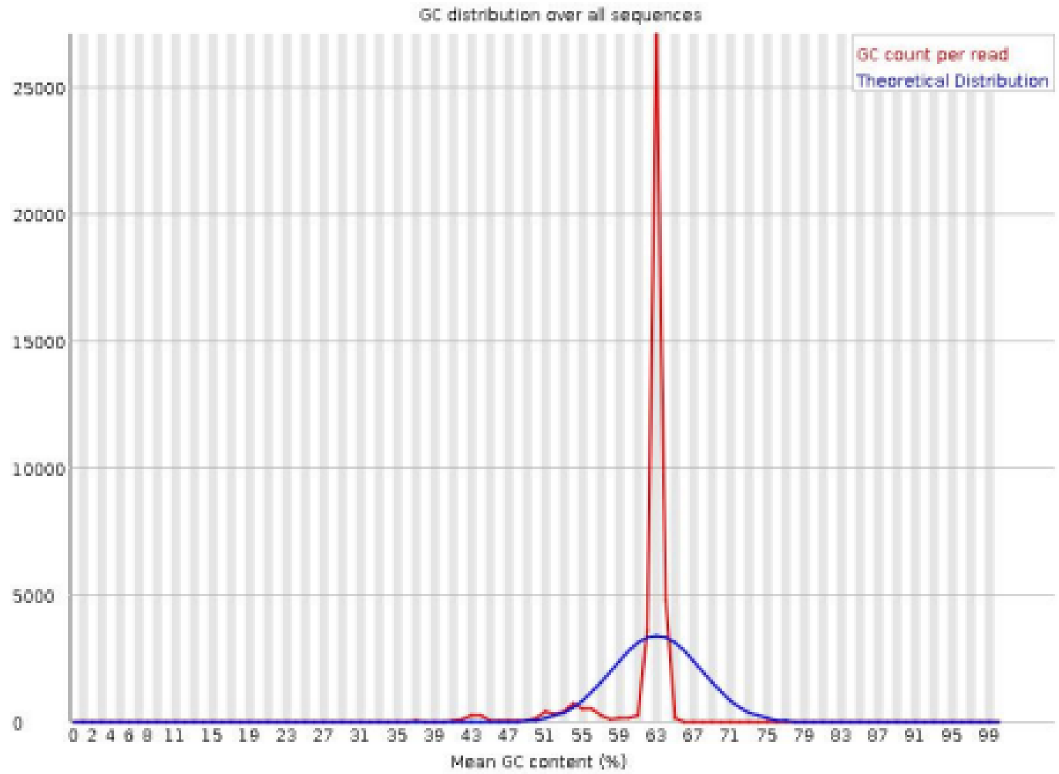
Annexure 65. Average base quality of R1 reads of Poyilkavu



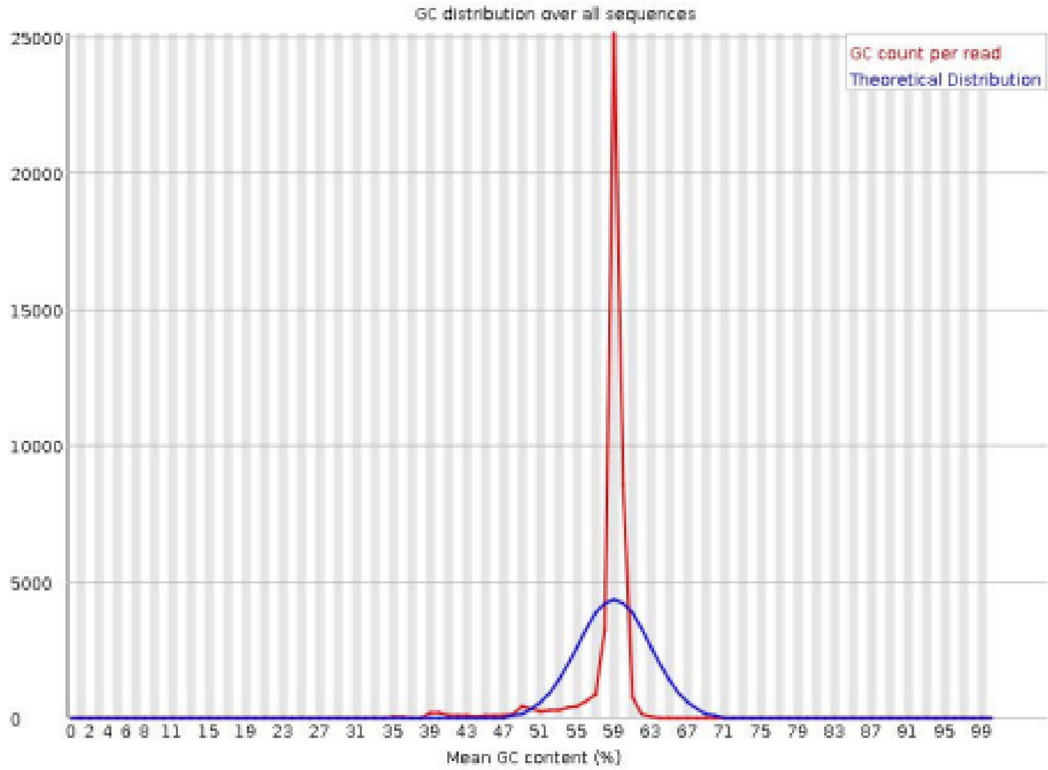
Annexure 66. Average base quality of R2 reads of Poyilkavu



Annexure 67. GC distribution of R1 reads of Poyilkavu



Annexure 68. GC distribution of R2 reads of Poyilkavu



Annexure 69. Table showing the taxonomic count of phylum obtained from different sacred groves during the metagenomics analysis

Phylum	ISG	KSG	PSG
Unidentified	27	35	46
Rozellomycota	4	205	23
Mortierellomycota	538	353	295
Chytridiomycota	56	17	14
Basidiomycota	217	1,425	1,641
Ascomycota	29,746	75,233	53,211

Annexure 70. Table showing the taxonomic count of class obtained from different sacred groves during the metagenomics analysis

Class	ISG	KSG	PSG
Agaricomycetes	41	343	1,406
Agaricostilbomycetes	0	3	2
Archaeorhizomycetes	0	0	7
Cystobasidiomycetes	15	72	6
Dothideomycetes	149	625	364
Eurotiomycetes	28,240	69,722	48,935
Exobasidiomycetes	0	8	0
Geminibasidiomycetes	7	0	51
Leotiomycetes	0	6	2
Microbotryomycetes	0	24	4
Mortierellomycetes	538	353	295
Orbiliomycetes	0	68	0
Pezizomycetes	41	18	75
Rhizophydiomycetes	40	0	0
Rozellomycotina cls Incertae sedis	0	35	0
Saccharomycetes	249	983	172
Sordariomycetes	1,018	3,720	3,564
Tremellomycetes	93	907	127
Ustilaginomycetes	0	5	0
Wallemiomycetes	15	28	11
unidentified	64	236	86

Annexure 71. Table showing the taxonomic count of order obtained from different sacred groves during the metagenomics analysis

Order	ISG	KSG	PSG
Agaricales	9	214	720
Agaricostilbales	0	3	2
Archaeorhizomycetales	0	0	7
Boletales	0	24	651
Botryosphaeriales	0	12	0
Cantharellales	0	0	6
Capnodiales	105	519	222
Chaetosphaeriales	144	57	33
Chaetothyriales	0	35	28
Cystobasidiales	15	69	6
Doassansiales	0	8	0
Dothideales	0	6	0
Erythrobasidiales	0	3	0
Eurotiales	28,228	69,687	48,907
Filobasidiales	2	25	6
Geminibasidiales	7	0	51
Glomerellales	11	15	21
Helotiales	0	6	2
Hypocreales	716	2,961	3,268
Leucosporidiales	0	19	0
Microascales	0	65	2
Mortierellales	538	353	295
Onygenales	12	0	0
Orbiliales	0	68	0
Pezizales	41	18	75
Pleosporales	44	88	142
Polyporales	29	73	19
Rhizophydiales	40	0	0
Saccharomycetales	249	983	172
Sebacinales	3	8	0
Sordariales	108	483	114
Sporidiobolales	0	5	4
Trechisporales	0	0	10
Tremellales	30	597	84
Trichosphaeriales	0	0	30
Trichosporonales	61	285	37
Ustilaginales	0	5	0
Wallemiales	15	28	11
Xylariales	31	113	31
Unidentified	64	236	86

Annexure 72. Table showing the taxonomic count of family obtained from different sacred groves during the metagenomics analysis

Family	ISG	KSG	PSG
Agaricostilbaceae	0	0	2
Amanitaceae	0	11	0
Amorosiaceae	0	0	33
Archaeorhizomycetaceae	0	0	7
Ascobolaceae	0	7	4
Ascodesmidaceae	39	0	71
Aspergillaceae	83	255	398
Bartaliniaceae	0	6	0
Bionectriaceae	40	38	69
Botryosphaeriaceae	0	12	0
Bulleribasidiaceae	6	58	24
Ceratobasidiaceae	0	0	6
Chaetomiaceae	50	431	114
Chaetosphaeriaceae	144	57	33
Chaetothyriaceae	0	14	0
Cladosporiaceae	99	354	211
Clavicipitaceae	0	38	45
Coniothyriaceae	3	0	0
Cordycipitaceae	0	53	0
Cucurbitariaceae	12	24	49
Cystobasidiaceae	15	69	6
Debaryomycetaceae	0	9	0
Diatrypaceae	0	0	3
Doassansiaceae	0	8	0
Dothideales fam Incertae sedis	0	6	0
Erythrobasidiaceae	0	3	0
Filobasidiaceae	2	25	6
Ganodermataceae	24	47	19
Geminibasidiaceae	7	0	51
Glomerellaceae	0	4	9
Herpotrichiellaceae	0	21	11
Hydnodontaceae	0	0	10
Hygrophoraceae	0	0	29
Hypocreaceae	100	876	1,631
Hypocreales fam Incertae sedis	175	106	296
Inocybaceae	9	139	634
Kondoaceae	0	3	0
Leotiaceae	0	3	0
Leucosporidiaceae	0	19	0
Lipomycetaceae	0	9	7

Meripilaceae	0	14	0
Meruliaceae	0	6	0
Microascaceae	0	65	0
Microdochiaceae	7	0	0
Morosphaeriaceae	4	0	0
Mortierellaceae	538	268	295
Mycosphaerellaceae	3	145	8
Nectriaceae	326	1,426	1,053
Onygenaceae	12	0	0
Ophiocordycipitaceae	0	3	9
Orbiliaceae	0	68	0
Pezizales fam Incertae sedis	2	0	0
Phaeosphaeriaceae	2	0	6
Phaffomycetaceae	0	13	0
Physalacriaceae	0	0	5
Pichiaceae	39	51	4
Plectosphaerellaceae	11	11	12
Pleosporaceae	9	0	26
Pleosporales fam Incertae sedis	3	5	0
Polyporaceae	5	6	0
Psathyrellaceae	0	7	6
Rhynchogastremataceae	0	4	0
Saccharomycetaceae	0	0	3
Saccharomycetales fam Incertae sedis	150	789	153
Sclerodermataceae	0	24	651
Sclerotiniaceae	0	3	2
Sebacinaceae	3	0	0
Sordariales fam Incertae sedis	21	0	0
Sporidiobolaceae	0	5	4
Sporormiaceae	0	24	0
Stachybotryaceae	70	331	160
Terramycetaceae	40	0	0
Tetraplosphaeriaceae	0	10	0
Thyridariaceae	11	25	0
Tremellaceae	6	0	0
Trichocomaceae	28,145	69,432	48,509
Trichosphaeriaceae	0	0	30
Trichosporonaceae	61	285	37
Trimorphomycetaceae	18	535	60
Ustilaginaceae	0	5	0
Wallemiaceae	15	28	11
Xylariaceae	16	49	6
Xylariales fam Incertae sedis	8	41	22
unidentified	99	289	113

Annexure 73. Table showing the taxonomic count of genus obtained from different sacred groves during the metagenomics analysis

Genus	ISG	KSG	PSG
Acaulium	0	3	0
Acremonium	163	62	241
Acrocalymma	4	0	0
Alternaria	9	0	21
Amanita	0	11	0
Amesia	0	89	22
Angustimassarina	0	0	33
Apiotrichum	35	23	8
Arachnotheca	12	0	0
Archaeorhizomyces	0	0	7
Arthrobotrys	0	68	0
Ascobolus	0	7	4
Ascotricha	6	16	0
Aspergillus	64	215	185
Bartalinia	0	6	0
Beauveria	0	53	0
Bionectria	24	0	0
Bipolaris	0	0	5
Botryotrichum	0	0	17
Campylocarpon	0	32	0
Candida	150	789	153
Cephaliophora	39	0	71
Chaetomium	0	13	0
Chloridium	122	57	33
Cladophialophora	0	0	5
Cladosporium	96	339	202
Clonostachys	16	38	56
Colletotrichum	0	4	9
Coniothyrium	3	0	0
Coprinellus	0	7	6
Cordana	21	0	0
Cryptococcus	6	0	0
Cryptocoryneum	3	0	0
Cyberlindnera	0	13	0
Cystobasidium	15	69	6
Dekkera	39	51	4
Emericellopsis	0	17	23
Erythrobasidium	0	3	0
Filobasidium	0	21	6
Flammulina	0	0	5

Funalia	5	0	0
Fusarium	17	110	110
Ganoderma	24	47	19
Geminibasidium	7	0	51
Gibberella	0	36	15
Gibellulopsis	11	0	12
Gliocephalotrichum	0	0	7
Gorgomyces	0	3	0
Hansfordia	8	34	22
Heterodoassansia	0	8	0
Hexagonia	0	6	0
Humicola	0	52	17
Hygrocybe	0	0	29
Hypoxylon	3	0	0
Ilyonectria	0	6	0
Inocybe	9	139	634
Kazachstania	0	0	3
Kernia	0	5	0
Kondoa	0	3	0
Kurtzmaniella	0	9	0
Lasiodiplodia	0	12	0
Leucosphaerina	6	0	5
Leucosporidium	0	19	0
Lipomyces	0	9	7
Mariannaea	30	127	13
Memnoniella	51	286	152
Metacordyceps	0	28	42
Metarhizium	0	10	3
Moesziomyces	0	5	0
Mortierella	538	268	295
Mycosphaerella	0	76	0
Naganishia	2	4	0
Nemania	0	0	6
Neocosmospora	222	927	755
Nigrospora	0	0	30
Papiliotrema	0	4	0
Penicillifer	0	140	25
Penicillium	19	40	213
Peroneutypa	0	0	3
Petriellopsis	0	7	0
Phaeosphaeria	0	0	6
Phialemoniopsis	0	7	0
Phialophora	0	21	6
Phlebia	0	6	0

Plectosphaerella	0	11	0
Preussia	0	6	0
Pseudallescheria	0	50	0
Pseudorobillarda	0	5	0
Pyrenochaetopsis	12	24	49
Ramularia	0	0	3
Rhodotorula	0	5	4
Roussoella	11	25	0
Saitozyma	18	535	60
Sarocladium	6	27	27
Scleroderma	0	24	651
Sebacina	3	0	0
Selenophoma	0	6	0
Septoria	3	14	5
Setophoma	2	0	0
Stephanonectria	22	0	0
Sterigmatomyces	0	0	2
Stilbocrea	0	0	13
Talaromyces	28,134	69,427	48,493
Terramyces	40	0	0
Tetraploa	0	10	0
Thanatephorus	0	0	6
Thermomyces	11	0	16
Tolypocladium	0	3	9
Toxicocladosporium	3	15	9
Trechispora	0	0	10
Trichobolus	2	0	0
Trichoderma	100	876	1,631
Trichosporon	26	262	29
Vishniacozyma	6	58	24
Wallemia	15	28	11
Westerdykella	0	18	0
Xerochrysium	0	5	0
Xylaria	7	25	0
Zopfiella	50	271	58
Unidentified	121	317	113

Annexure 74. Table showing the taxonomic count of species obtained from different sacred groves during the metagenomics analysis

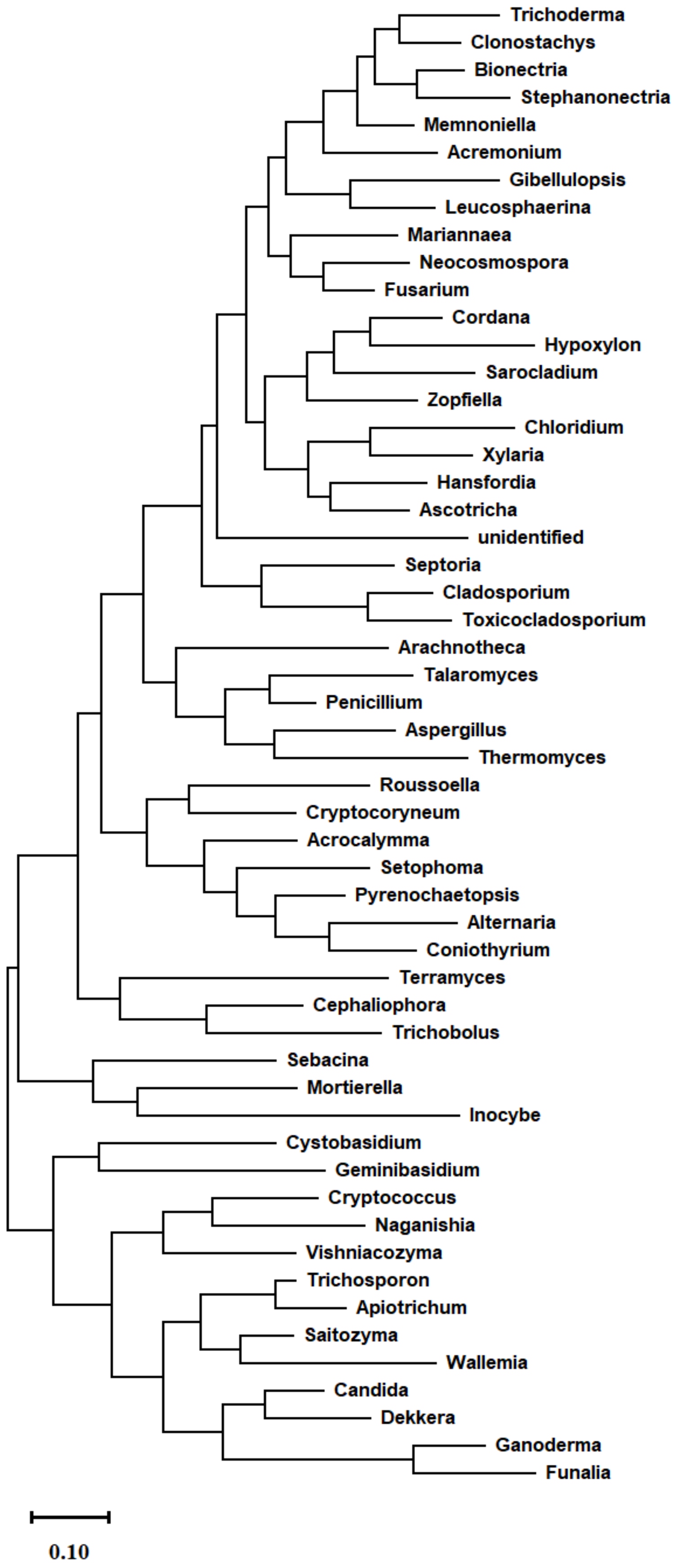
Species	ISG	KSG	PSG
Acremonium acutatum	6	0	0
Acremonium alternatum	130	0	226
Acremonium hennebertii	20	0	0
Acremonium persicinum	0	28	15
Acremonium pinkertoniae	0	26	0
Acremonium polychromum	7	0	0
Acremonium tubakii	0	8	0
Alternaria angustiovoidea	9	0	21
Amanita inopinata	0	11	0
Amesia atrobrunnea	0	89	22
Angustimassarina acerina	0	0	33
Apiotrichum dehoogii	12	0	8
Apiotrichum scarabaeorum	23	23	0
Arachnotheca glomerata	12	0	0
Ascobolus foliicola	0	7	4
Ascotricha guamensis	6	16	0
Aspergillus diversus	0	0	11
Aspergillus heterocaryoticus	6	0	0
Aspergillus penicillioides	16	59	82
Aspergillus ruber	0	0	45
Aspergillus subversicolor	0	22	0
Aspergillus sydowii	0	25	25
Bartalinia pondoensis	0	6	0
Beauveria felina	0	53	0
Bionectria rossmaniae	24	0	0
Bipolaris urochloae	0	0	5
Botryotrichum atrogriseum	0	0	17
Candida albicans	0	14	0
Candida ethanolica	117	642	97
Candida hyderabadensis	10	52	39
Candida pseudojiufengensis	3	11	0
Candida tropicalis	20	70	17
Cephaliophora tropica	39	0	71
Chaetomium longicolleum	0	13	0
Chloridium aseptatum	122	57	33
Cladosporium sphaerospermum	0	64	25
Cladosporium tenuissimum	74	190	89
Cladosporium velox	0	25	68
Clonostachys chlorina	0	0	48
Clonostachys compactiuscula	0	38	0

Colletotrichum xanthorrhoeae	0	4	0
Coniothyrium multiporum	3	0	0
Coprinellus domesticus	0	7	6
Cordana bisbyi	21	0	0
Cryptococcus uniguttulatus	6	0	0
Cryptocoryneum brevicondensatum	3	0	0
Cyberlindnera sargentensis	0	13	0
Cystobasidium fimetarium	15	69	6
Dekkera bruxellensis	39	51	4
Erythrobasidium hasegawianum	0	3	0
Filobasidium oeirense	0	21	6
Flammulina velutipes var. *himalayana*	0	0	5
Funalia floccosa	5	0	0
Fusarium delphinoides	9	10	100
Fusarium solani	0	19	0
Ganoderma gibbosum	24	47	13
Gliocephalotrichum humicola	0	0	7
Gorgomyces hungaricus	0	3	0
Hansfordia pulvinata	8	0	0
Heterodoassansia hygrophilae	0	8	0
Hexagonia tenuis	0	6	0
Humicola sardiniae	0	52	17
Hygrocybe glutinipes	0	0	29
Hypoxylon hypomiltum	3	0	0
Ilyonectria macrodidyma	0	6	0
Inocybe gregaria	9	139	634
Kazachstania africana	0	0	3
Kernia geniculotricha	0	5	0
Kondoa sorbi	0	3	0
Lasiodiplodia margaritacea	0	12	0
Leucosphaerina arxii	6	0	5
Leucosporidium scottii	0	19	0
Lipomyces yarrowii	0	9	7
Mariannaea camptospora	0	45	0
Mariannaea punicea	30	82	13
Memnoniella longistipitata	51	286	152
Metacordyceps chlamydosporia	0	28	42
Metarhizium anisopliae	0	10	3
Moesziomyces antarcticus	0	5	0
Mortierella alpina	0	40	0
Mortierella amoeboidea	11	36	109
Mortierella capitata	0	16	0
Mortierella epigama	5	166	162
Mortierella formicae	102	0	0

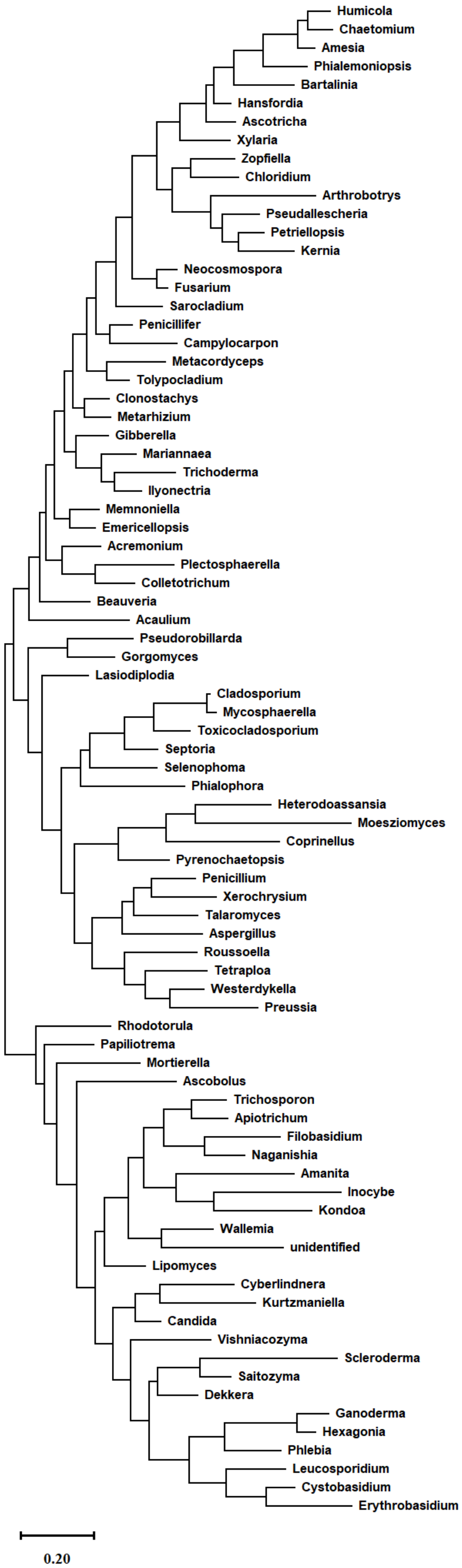
Mortierella minutissima	415	0	0
Mortierella polygonia	0	10	0
Mycosphaerella tassiana	0	76	0
Naganishia diffluens	2	4	0
Nemania primolutea	0	0	6
Neocosmospora falciformis	222	927	755
Papiliotrema mangalensis	0	4	0
Penicillifer diparietisporus	0	140	25
Penicillium arianeae	0	0	24
Penicillium citrinum	8	30	46
Penicillium longicatenatum	0	0	30
Penicillium malachiteum	11	0	0
Peroneutypa scoparia	0	0	3
Petriellopsis africana	0	7	0
Phaeosphaeria oryzae	0	0	6
Phialemoniopsis pluriloculosa	0	7	0
Plectosphaerella oratosquillae	0	11	0
Preussia terricola	0	6	0
Pseudallescheria angusta	0	50	0
Pyrenochaetopsis leptospora	12	24	49
Ramularia eucalypti	0	0	3
Rhodotorula sphaerocarpa	0	0	4
Rhodotorula toruloides	0	5	0
Roussoella solani	0	10	0
Saitozyma flava	0	260	0
Saitozyma podzolica	18	275	60
Sarocladium oryzae	6	27	27
Scleroderma sinnamariense	0	24	651
Selenophoma mahoniae	0	6	0
Septoria cretae	3	14	5
Setophoma chromolaenae	2	0	0
Stephanonectria keithii	22	0	0
Sterigmatomyces halophilus	0	0	2
Talaromyces albobiverticillius	22	0	10
Talaromyces neofusisporus	0	128	0
Talaromyces tzapotlensis	14	0	0
Thanatephorus cucumeris	0	0	6
Toxicocladosporium irritans	3	15	9
Trichobolus zukalii	2	0	0
Trichoderma hunanense	0	0	610
Trichoderma lixii	73	352	908
Trichoderma turrialbense	0	67	0
Trichoderma virilente	0	27	32
Trichosporon asahii	26	146	29

Trichosporon ovoides	0	116	0
Vishniacozyma carnescens	2	0	5
Vishniacozyma taibaiensis	4	41	19
Vishniacozyma victoriae	0	17	0
Westerdykella nigra	0	7	0
Xerochrysium dermatitidis	0	5	0
Xylaria cubensis	0	25	0
Unidentified	225	736	308

Annexure 75. Phylogenetic tree of Iringole Kavu



Annexure 76. Phylogenetic tree of Kollakal Thapovanam



Annexure 77. Phylogenetic tree of Poyilkavu