Systematic studies on the clavarioid fungi (Agaricomycetes, Basidiomycota) of Kerala

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by
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February 2023

CERTIFICATE

This is to certify that the thesis entitled "**Systematic studies on the clavarioid fungi (Agaricomycetes, Basidiomycota) of Kerala**", submitted to the University of Calicut by Ms. Krishnapriya K., for the award of PhD. Degree in Botany is a record of Bonafide research work carried out by her under the supervision and guidance of Dr. Arun Kumar T. K., Assistant Professor, Post Graduate and Research Department of Botany of this College during the period 2017–2023.

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February 2023

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Dr. Arun Kumar T. K.

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DECLARATION

I hereby declare that the thesis entitled "**Systematic studies on the clavarioid fungi (Agaricomycetes, Basidiomycota) of Kerala**" submitted to the University of Calicut in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Botany, has been carried out by me under the supervision and guidance of Dr. Arun Kumar T. K., Assistant Professor, Post Graduate and Research Department of Botany, and that no part of this thesis has formed the basis for the award of any degree or diploma or other similar title or recognition.

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1. INTRODUCTION

Clavarioid fungi are a group of Agaricomycetes (Basidiomycota), which includes about 1500 species in 30 genera belonging to different fungal orders (Ottoni *et al.* 2017; www.indexfungorum.org). The sexual structures, called basidiocarps, produced by these fungi are usually fleshy, non-gilled, and may be simple, club-shaped, or branched coral-like structures. The spore-bearing surface of the basidiomata is typically smooth or ridged, occasionally warted, or weakly spiny. The basidiocarps are distinguished by their colour variations, ranging from pale to bright shades (Corner 1950; Petersen 1988).

Clavarioid fungi in general are saprotrophic, play a major role in the decomposition of dead plant matter, and are efficient in nutrient recycling (Corner 1950, 1970; Petersen 1988; Nelsen *et al.* 2007; Henkel *et al.* 2012; Ottoni *et al.* 2017). They exhibit life strategies that range from saprotrophism to parasitism to ectomycorrhizal and lichenized mutualism (Corner 1950, 1970; Petersen 1988; Pine *et al*. 1999; Dentinger & McLaughlin 2006; Nelsen *et al*. 2007; Henkel *et al.* 2012; Ottoni *et al.* 2017). These life strategies make this fungal group excellent candidates for ecological studies (Shiryaev & Iršėnaitė 2009). *Clavulina rugosa* (Bull.) J. Schröt., *Phaeoclavulina camellia* (Corner) Giachini, *P. eumorpha* (P. Karst.) Giachini, *Ramaria aureofulva* Corner, and *R. reticulata* (Berk. & Cooke) Corner are examples of ectomycorrhizal clavarioids (Sulzbacher *et al.* 2012). Species in the genera *Ertzia*, *Multiclavula*, *Lepidostroma*, and *Sulzbacheromyces* are lichenized (Ertz *et al.* 2008; Hodkinson *et al.* 2014).

Many clavarioid fungi are of nutritional value. Majority of the species belonging to the genera *Clavaria, Clavulina, Clavulinopsis, Ramaria*, and *Ramariopsis* are edible. *Clavulina albiramea* (Corner) Buyck & Duhem, *C. wisoli* R.H. Petersen (Duhem & Buyck 2007), *C. kunmudlutsa* T.W. Henkel & Heim, *C. tepurumenga* T.W. Henkel & Heim (Henkel *et al.* 2012a), *Clavaria fragilis* Holmsk. (Miller & Miller 2006), *C. rosea* Dalman, *Clavulinopsis amoena (Zoll. & Moritzi) Corner, Ramaria botrytis (Pers.) Bourdot, R. flava* (Schaeff.) Quel., *R. flavescens*

(Schaeff.) R.H. Petersen (Sharma & Gautam 2017), *Ramariopsis kunzei* (Fr.) Corner (Tylutki 1979) are reported as edible. Clavarioid fungi are also rich in potentially bioactive compounds (Coker 1923; Thind 1961; Ramesh & Pattar 2010; Liu *et al.* 2013; Hrudayanath & Sameer 2014; Sharma & Gautam 2017). *Clavaria zollingeri* Lev., *Ramaria apiculata* (Fr.) Donk, *R. aurea* (Schaeff.) Que´l., *R. flava* (Schaeff.) Que´l., *R. formosa* (Pers.) Que´l., and *R. hemirubella* R.H. Petersen & M. Zang possess anti-tumour, antioxidant, and antibacterial properties (Dai *et al.* 2009; Giri *et al*. 2012; Sadi *et al*. 2016; Li 2017; Zhou *et al.* 2017; Dong *et al.* 2017; Sheng *et al*. 2018). *R. formosa* is also reported as a neutrophil elastase inhibitor (Kim *et al.* 2015). Some species of *Scytinopogon,* such as *S. echinosporus* (Berk. & Broome) Corner, have been reported to have disinfecting, hemostatic, and detoxification properties. Amino acids such as conjugated diene amino acids, L-azetidine-2-carboxylic acid, 3-methyllanthionine, and 2-amino-3,5-hexadienoic acid have been isolated from *Clavulinopsis helvola* (Pers.) Coner (Aoyagi *et al.* 1997).

Clavarioid species like *Clavulinopsis dichotoma* (God.) Corner cause sickness when consumed. *Ramaria formosa* (Fr.) Quel. and *R. mairei* Donk are reported to be poisonous and have been known to cause diarrhea. Specimens of *R. rufescens* (Fr.) Corner have been used as purgative (Thind 1961). The clavarioid genus *Typhula* is known to be pathogenic or parasitic on higher plants. *Typhula* blight disease of cereals are caused by *Typhula incarnata* Lasch and *T. ishikariensis* S. Imai, and have been widely reported from Europe and Japan. *T. trifolii* Rostr. attacks stem and leaves of clovers, *T. umbrina* Remsberg attacks roots of *Brassica campestris* while *T. betae* Rostr. parasitizes roots and stems of *Beta* in Europe (Lawton & Burpee 1990; Thind 1961; Boulter *et al.* 2002). *T. phacorrhiza* (Reichard) Fr. is used as a biological control agent against *Typhula* blight (caused by *T. ishikariensis* S. Imai, and *T. incarnata* Lasch) of creeping bentgrass (Lawton & Burpee 1990).

Clavarioid fungi have been documented worldwide (Fries 1821: Cotton 1906; Atkinson 1909; Cotton & Wakefield 1919; Burt 1914, 1922; Buller 1922; Coker 1923, 1947; Imai 1930; Fawcett & Stella 1938; Martin 1940; Doty 1944, 1947, 1948a, 1948b; Corner 1950, 1952a, 1952b, 1952c, 1953,1970; Eriksson 1954; Petersen

1967a, 1967b, 1967c, 1971c, 1978a, 1978b, 1978c, 1979, 1983, 1985, 1988; Dodd 1972; Englander & Hull 1980; McAfee & Grund 1982; Domanski 1984; Julich 1985; Daun & Nitare 1987; Pellegrini & Patrignani 1994; Robert 1999; Pine *et al*. 1999; Govorova & Sazanova 2000; Lickey *et al.* 2003; García Sandoval *et al.* 2005; Dentinger & McLaughlin 2006; Kautmanová *et al.* 2012a,b; Knudsen & Shiryaev 2012; Olariaga & Salcedo 2012; Birkebak *et al.* 2013; Shiryaev 2004, 2006, 2008a, 2008b, 2009a, 2009b, 2012, 2013; Olariaga *et al.* 2015; Furtado *et al.* 2016; Olariaga *et al* 2020; Yan *et al.* 2020; Franchi & Marchetti 2021; Liu *et. al.* 2022), and many species have a cosmopolitan distribution. Although species diversity, distribution, and ecology of clavarioid fungi have been fairly well studied around the globe, molecular phylogenetic studies that includes tropical taxa are sparse.

Some of the major Indian records on clavarioid fungi include those of Leveille (1844), Berkeley (1856), Butler & Bisby (1931), Banerjee & Ganguli (1945), Banerjee (1947), Ahmad (1949), Ramakrishnan & Subramanian (1952), Thind (1956a, 1956b, 1957a 1957b, 1961), Thind & Sukh Dev (1956), Thind & Raswan (1958), Thind & Anand (1956), Parndekar (1964), Thind & Rattan (1967), Thite *et al.* (1976), Patil & Thite (1977), Sharma & Munjal (1977), Sharma & Janadaik (1978), Khurana (1980), Thind & Sharda (1984), Methven (1989), Das (2009), Dehariya *et al.* (2010), Senthilarasu (2013a, 2013b), Tiwari *et al.* (2013), Das *et al*. (2016), Verma & Pandro (2018), Das *et al*. (2020).

The only published report of clavarioid fungi from Kerala before the commencement of the study is by Mohanan (2011), where 19 species were recorded. The fungal diversity of the state is underexplored, and the biodiversity richness of the state indicates that many more clavarioid species are yet to be documented. Concerted exploratory studies on the clavarioid fungi of Kerala using morphological and molecular techniques will help gauge the diversity of the group in Kerala. A phylogeny-based approach with the available species data and new data generated on the group from Kerala is also expected to aid in resolving many confusions that exist regarding the taxonomic concepts of the group. With these in mind, a comprehensive systematic study of the clavarioid fungi of Kerala is attempted.

Objectives of the study:

1) To prepare a systematic account of clavarioid fungi (Agaricomycetes, Basidiomycota) of Kerala.

2) To understand the phylogenetic relationships of clavarioid fungi of Kerala.

2. REVIEW OF LITERATURE

2.1. CLAVARIOID FUNGI

Clavarioid fungi are a diverse group of Basidiomycota members, composed of species that produce simple clubs to branched coralloid basidiomata having smooth or wrinkled hymenophores (Pine *et al.* 1999; Birkebak 2015). They are represented in different orders (Agaricales Underw., Cantharellales Gaum., Gomphales Julich, Hymenochaetales Oberw., Lepidostromatales B.P. Hodk. & Lücking, Russulales Kreisel ex P.M. Kirk, P.F. Cannon & J.C. David, Sebacinales M. Weiss, Selosse, Rexer, A. Urb. & Oberw., Trechisporales K.H. Larss, and Tremallodendropsidales Vizzini) of the class Agaricomycetes (Corner 1970; Petersen 1988; Pine *et al.* 1999; Dentinger & McLaughlin 2006; Kirk *et al*. 2008; Birkebak *et al.* 2013; Ottoni *et al.* 2017; Olariaga *et al.* 2020). The clavarioid fructifications are colourful, and pigmentation ranges from white to greyish, yellow, orange, brown, pink, violet and black. Basidiomatal colour has been used as a key taxonomic character in delimiting species and also for informal grouping of species within the genus (Corner 1950; Knudsen 1997b; Petersen 1978a; Petersen 1999; Roberts 2007; Kautmanová *et al.* 2012b). Although this group generally exhibits very limited morphological characters, it shows adaptive convergence. Hence, its evolutionary morphology is complicated (Hibbet 2004; Dentinger & McLaughlin 2006).

Clavarioid fungi are easily recognizable in the field due to their unique shapes, and distinctive colours. Although they can be easily recognized from other groups of fungi, the variations observed in generic and infrageneric characters have always made this group confusing in species-level identifications. Many earlier workers, like Scopoli & Antonio (1772), Schäffer & Christian (1774), Muller (1780), Batsch (1786), Shrank (1789), Bolton (1790), Holmskjold (1790), Bulliard (1791), Withering (1792), Persoon (1797a,b,c, 1822), Sowerby (1803), Schumacher (1803), Fries (1821, 1828, 1838, 1874a,b), Berkley & Broome (1850), Hooker (1855), Gillet (1874), Britzelmayr (1887), Morgan (1888), Saccardo (1888), Pattouillard & Gaillard (1888), Massee (1892) and Peck (1894) used a system which aligned all the clavarioid taxa in a single genus, *Clavaria*. In 1821, it was Fries who introduced the "Clavariaceae" as one of the five families of Agaricales. Later, in 1826, All species with superficially

similar coral-like basidiomata were placed in the Clavariaceae family. These works were purely based only on macroscopic characters (except that of Fries (1838) and Karsten (1879)). Fries (1838) divided the genus *Clavaria* into tribes based on the morphology of the basidiomata, and spore characters. These characters were also used by Karsten (1879) in his clavarioid studies (McAfee & Grund 1982). In the nineteenth century, increased use of microscopy led to the discovery of new genera, and also resulted in the transfer of many members from Basidiomycota to Ascomycota.

In later studies on clavarioid fungi, it became necessary to examine the spore characters for accurate species identification. It was Cotton (1906), in his "Notes on British Clavariaceae," who paid special attention to the spore and its value as a diagnostic character (Petersen 1969). With the implementation of the International Code of Botanical Nomenclature and improved light microscopic methods in the beginning of the last century, several monographic treatments of clavarioid fungi appeared (Kautmanová *et al.* 2012). The first such monographic treatment of this group was done by Cotton and Wakefield (1919) from Britain. They listed 37 species of *Clavaria* using field characters along with microscopic characters such as the shape and size of the basidiospores. Later, Harper (1918), Cleland (1916, 1931, 1935), Burt (1922), Kauffmann (1927), Fawcett (1938), and Coker (1947) studied clavarioid fungi from the tropics. They all added new species but not new genera (Petersen 1973). Rea (1922) placed the clavarioid group, including fleshy club-to-coral-shaped fungi, in the highly polyphyletic order Aphyllophorales (Birkebak *et al.* 2013).

The first and largest publication on clavarioid fungi was by Coker (1923). He divided the family Clavariaceae into six genera: *Lachnocladium, Pterula, Clavaria, Pistillaria, Typhula,* and *Physalacria.* Coker (1923) introduced his concept of 11 informal groups in *Clavaria sensu lato* based on their structure, and indicated that those groups might be accepted as genera or subgenera (Petersen 1973). Petersen (1973) reported 91 species under the genus *Clavaria,* one each in *Pterula* and *Lachnocladium,* and two in *Typhula* (Coker 1923). The name *Clavaria* was still used for the majority of the basidiomycetous species until Donk (1933) reviewed the Dutch species. Donk (1933) described the present-day genus *Clavulina* as a tribe in *Canthrelloidae, Clavaria* as a tribe in *Clavarioidae,* and the genus *Ramariopsis* as a subgenus in the tribe *Clavaria.* Donk (1933) also introduced a new genus, *Clavariadelphus,* with club-shaped basidiomata (Petersen 1972).

Following Coker's (1923) concept of *Clavaria*, Doty (1944) presented a taxonomic key to the *Clavaria* species of the Pacific Northwest (Petersen 1973). In that work, Doty introduced 51 species of *Clavaria* and divided the genus into six sections (Doty 1944). However, Doty's concept was very broad, according to Petersen (1973). In 1947, Doty proposed a new genus, *Clavicorona* (Petersen 1973; Lickey *et al.* 2003). Later, Doty (1948b) offered a preliminary key to the clavarioid genera, in which he revived many less recognized genera and split the Clavariaceae *sensu lato* into smaller genera (Petersen 1973). The group was later reclassified into a more natural taxonomic assemblage (Birkebak *et al*. 2013).

Corner (1950), in his "Monograph of *Clavaria* and allied genera", introduced most of the remaining modern genera. Corner's (1950) was the only global monograph of clavarioid fungi that critically revised all the recognized taxa described thus far. Corner (1950) introduced a new classification for the clavarioid fungi in his monograph. In his monograph, Corner (1950) recognized 540 species from 27 clavarioid and allied genera from tropical regions based on extensive field work and the examination of herbarium specimens. Corner (1950) segregated the clavarioid genera into seven groups, including the genus *Clavicorona* (Table 1).

TABLE 1: Corner's (1950) clavarioid groups.

Groups	Genera
Pteruloid series	*Dimorphocystis, Deflexula, Pterulicium, Pterula*
Xanthochroic series	*Clavariachaete, Lachnocladium*
Thelephoroid series	*Aphelaria, Scytinopogon, Thelephora*
***Ramaria* series**	*Ramaria, Lentaria*
***Clavariadelphus* series**	*Araeocoryne, Caripia, Ceratellopsis, Chaetotyphula, Clavariadelphus, Hormomitaria, Myxomycedium, Mucronella, Pistillina, Pistillaria, Physalacria, Typhula*
***Clavaria* series**	*Clavaria, Clavulina, Clavulinopsis, Ramariopsis*
Clavicorona	*Clavicorona*

A natural classification of the Aphyllophorales was put forward by Donk (1964). Donk recognized 18 genera in the family Clavariaceae. Corner (1970), in his "Supplement to the Monograph of Clavarioid Fungi" used a modified version of

Donk's classification (Dentinger & McLaughlin 2006). In that, Corner recognized 38 clavarioid genera in 12 families. Petersen's studies (1967a, 1967b, 1968a, 1969, 1971b, 1972, 1973, 1978b) advanced the knowledge of the diversity of clavarioid fungi. These were based on Petersen's studies of the collections from North America, Australia, and New Zealand (Petersen 1968a, 1978b, 1978c, 1979, 1988). Petersen (1967d) proposed a new genus *Multiclavula* for small, lichenized, unbranched clavarioid fungi (Pine *et al.* 1999). In his work, Petersen (1978a) reorganized the classification of the family Clavariaceae, in which he recognized only two genera, *Clavaria* and *Ramariopsis*. *Clavulinopsis* was recognized only as one of the three subgenera of the genus *Clavaria* other than subgenus *Clavaria* and subgenus *Holocoryne* (Dentinger & McLaughlin 2006).

The widely known and used taxonomic key for identification of European clavarioid fungi is by Jülich (1984), and is based mostly on works by Corner and Petersen. Jülich (1984) transferred all species of *Ramariopsis* to *Clavulinopsis*. Many evolutionary theories exist regarding the origin of the clavarioid group. From his observations and studies on clavarioid fungi, Corner (1970) proposed that the evolutionary ancestor of homobasidiomycetous mushrooms was clavarioid, from which all other basidiomatal forms were derived through transitional series (Pine *et al.* 1999; Dentinger & McLaughlin 2006). Corner (1970) proposed the *Clavaria* theory, which treats cantherelloid and clavarioid fungi as paraphyletic groups from which other Homobasidiomycetes are derived. He suggested that "the simple club with a smooth hymenophore is the ancestral state of the fleshy fungi" (Pine *et al.* 1999). Later, some more theories were developed on the origin of clavarioid fungi, which were strongly influenced by Corner's theory. Jülich (1981) suggested that the Clavariaceae must have been derived from the Auriculariales or their ancestors. Miller & Watling (1987) state that "cantharelloid basidiomes are the logical extension of the clavarioid condition among epigeous taxa" (Pine *et al.* 1999). Fiasson & Arpin (1967), Petersen (1971b), and Singer (1986) agreed with the view that transformations occur among coralloid, cantharelloid, and agaricoid forms, but suggested that lineages containing cantharelloid, coral, and club fungi must have been derived from agaricoid

ancestors (Pine *et al.* 1999). All the above postulations were made only based on morphological observations.

Morphology based studies in the clavarioid group did not resolve the uncertainty that existed in species-level identification. More advanced phylogenetic studies were required to resolve this delimitation in species level identification. In the late twentieth century, to resolve the complications regarding the classification of this group, further studies were conducted. Pine *et al.* (1999) studied the phylogenetic relationships of the families within the clavarioid group using molecular techniques. Using nuclear and mitochondrial ribosomal RNA loci, he demonstrated that the clavarioid fungi are polyphyletic, with affinities to the Agaricales. Moreover, Pine *et al.* (1999) clarified that coral fungi have been derived multiple times from diverse lineages and do not represent an ancestral group that gave rise to the more complex basidiomatal forms found in the basidiomycetes. According to Hibbet (2004), clavarioid forms are the most unstable basidiomatal forms in Homobasidiomycetes. Dentinger & McLaughlin (2006) examined the phylogenetic diversity of the Clavariaceae *sensu lato* using nuclear large subunit rDNA sequences, and indicated that the clavarioid morphology had evolved at least five times in the euagarics. Molecular studies revealed that the clavarioid morphology is homoplastic (Pine *et al.* 1999; Moncalvo *et al.* 2000), and that there have been frequent transitions between the clavarioid and either agaricoid (Hibbett 2004) or corticioid morphologies in the Homobasidiomycetidae (Hibbett & Binder 2002; Larsson *et al.* 2004; Binder *et al.* 2005; Dentinger & McLaughlin 2006). Kautmanová *et al.* (2012) revised the taxonomic concept and systematic positions of some Clavariaceae species from Central and Western Europe. She considered the species boundaries in darkly pigmented *Clavaria* with a nuc 28S rDNA phylogeny. A 28S sequence-based phylogeny by Birkebak *et al*. (2013) revealed that some agaricoid, corticioid and hydnoid genera belonged to Clavariaceae. Olariaga *et al*. (2015) discussed the phylogeny and circumscription of the genus *Clavaria* using the nuc 28S rDNA and internal transcribed spacer (ITS) region to resolve species relationships. Phylogenetic studies were also carried out in *Ramariopsis* (Garcia-Sandoval *et al.* 2005), *Gomphus*

(Giachini 2004; 2011), and pteruloid and typhuloid members (Leal-dutrra *et al.* 2020; Olariaga *et al*. 2020).

2.2. TAXONOMIC CHARACTERS

Macroscopic basidiomatal characters

Clavarioid fungi are easily distinguishable from other groups of fungi by their unique basidiomatal forms and colours. Basidiomatal form varies from unbranched club to branched coralloid basidiomata. Compared with other agaricoid groups, clavarioid fungi have few diagnostic microscopic characters. Species-level identification relies mostly on spore characters and in the presence of clamp-connections (Kautmanová *et al.* 2012). Characters used for species delimitation, like the colour, shape, and size of basidiomata and spore characters, have not been evaluated with molecular tools (Olariaga *et al*. 2015). Ornamentation of spores is the only character that distinguishes some clavarioid species (Petersen 1988; Knudsen 1997b; Olariaga *et al.* 2015).

Basidiomata are mostly erect, simple clavate, and slender or club-shaped (*Clavaria, Clavulinopsis*), or branched to form a coral-like structure (*Ramaria, Ramariopsis*), or may be dendroid (*Pterula*). Rarely, decumbent forms are also encountered. The size of the basidiomata varies from a few millimeters to about fifteen centimeters in height in some clavarioids. Basidiomatal size may vary with collections from different localities (Thind 1961) and may be soft, fleshy, brittle or waxy, or tough and pliable (McAfee & Grund 1982). Basidiomata are typically gymnocarpic, produced directly from the mycelium, or, in species with massive growth (*Ramaria*), from rhizomorphs (Corner 1950; Thind 1961). Basidiomata grow solitarily or as caespitose clusters, are gregarious, or may be densely packed together (Corner 1950; Thind 1961).

The branching pattern of basidiomata in clavarioid fungi is mostly radial or cylindrical (*Clavaria, Clavulina, Clavulinopsis, Ramaria,* and *Ramariopsis*), but are sometimes partly or fully flattened (*Aphelaria,* and *Scytinopogon*) (Thind 1961). Radial branching occurs in species with inflated hyphae, and flattened branching occurs in those without inflated hyphae (Corner 1950). The pattern of branching is

mostly dichotomous throughout, rarely polychotomous in some massive species of *Ramaria*, such as *R. botrytis* (Fr.) Rieken (Thind 1961). Very rarely, false monopodial branching is observed in some species of *Pterula* (Corner 1950). The apex of branches is usually acute, blunt, or round, but rarely pyxidate as in *Clavicorona*. The basidiomata of clavarioid fungi are typically erect but rarely decumbent, as in *Allantula*, or inverted, as in *Deflexula.* The trunk is usually sterile and may be smooth or rough due to the presence of puberulous, pubescent, strigose, or villose hairs (Thind 1961).

In clavarioid fungi, the colour of the basidiomata is much more important in the identification of taxa (Petersen 1988; Olariaga *et al.* 2015). They show a wide range of colours, such as, orange, yellow, brown, pink, red, violet, grey, or rarely green (*Ramaria*), and black (in some species of *Clavaria*). Different shades of a colour are usually present in one basidiomata (Corner 1950). Basidiomata of *Phaeoclavulina cyanocephala* (Berk. & M. A. Curtis) Giachini is brown-ochre to umber throughout while its tips are blue. Similarly, *Ramaria subdecurrens* (Coker) Corner possesses pallid ochraceous basidiomata with lavender-pink tips (Thind 1961). The context can be concolorous or in lighter shades. Colour changes of the context with bruising are often noticed. Certain species have a distinct smell, such as the basidiomata of *Clavaria cystidiata* Krishnapriya & T. K. A. Kumar, which have a strong garlic odour (Krishnapriya & Kumar 2021). Basidiomata of *Ramaria apiculata* (Fr.) Donk, an edible species is recorded to have a bitter taste (Thind 1961).

In clavarioid fungi, hymenium is typically amphigenous (Corner 1950; Thind 1961). In some species of the genera *Lachnocladium, Ramaria, Ramariopsis, Clavulina*, *Scytinopogon,* and *Lentaria*, the hymenium is unilateral, developing only on the underside of branches while the upper side is sterile, and *vice versa.* Species with villose or subtomentose basidiomata have the whole trunk sterile (Corner 1950; Thind 1961). However, according to Corner (1950), the placement of the hymenium cannot be considered as a constant character. The hymenium is typically smooth, rarely hispid, as in the case of *Clavulina hispidulosa* Corner, Thind & Anand (Thind 1961). In some simple filiform basidiomata of *Pterula,* the hymenium is partially or

completely absent (Corner 1950). Hymenium may be simple (not thickening) or compound (thickening). Simple hymenium is more commonly found in the smaller basidiomata of *Typhula, Pistillaria,* and some species of *Pterula.* Thickening of hymenium is a constant feature of *Clavulina* and *Clavariadelphus.* These two states of hymenium are variously present in *Clavaria*, *Clavulinopsis, Ramaria*, and *Lachnocladium* (Thind 1961).

Microscopic basidiomatal characters

Basidiospores

Basidiospore morphology, dimension, and ornamentation are primarily important in delimiting clavarioid taxa (Patouillard 1886; Petersen & Olexia 1969; McAfee & Grund 1982; Geesink & Bas 1992; Olariaga *et al.* 2015). Basidiospores show variation in their size, shape, and ornamentation. They range from globose to subglobose, ovoid, obovoid, ovate, ellipsoid, and elongate to amygdaliform (Thind 1961). They are typically hyaline or subhyaline (Pine *et al.* 1991), sometimes light pink to yellowish as in *Ramaria* and *Lachnocladium* (Corner 1950). Apiculus is prominent in some taxa, like *Clavulinopsis* (Kautmanová *et al.* 2012), and is sometimes inconspicuous. Spore ornamentation is very significant in this group of fungi. It varies from smooth to verrucose to warty to echinulate (with distinct spines). An echinulate, sharp-spined spore is a typical character of the genus *Ramaria* (Corner 1950, 1970). Angularly ellipsoid basidiospore is the characteristic feature of the genus *Scytinopogon* (now in *Trechispora*) (Corner 1950). Rarely, the spores are marked by longitudinal, fine striations, as in *Ramaria botritis* (Fr.) Rieken (Thind 1961). The spores may aguttulate or guttulate with one large oil droplet or one to several small oil droplets. Basidiospores are mostly inamyloid (Pine *et al.* 1991), but amyloid spores have been reported in the genera *Amylaria* (Thind 1961) and *Clavicorona* (Pine *et al.* 1991).

Basidia

Basidial structure is an important character in the identification of the clavarioid group (Petersen 1967c). Basidia may vary from subclavate, to clavate, or subcylindric to cylindrical (Thind 1961). Basidia are mostly hyaline, rarely pigmented. Basidial contents are homogeneous and sometimes guttulate. The presence or absence of basidial clamp-connection is a significant taxonomic character in clavarioid fungi (McAfee & Grund 1982). In some genera like *Clavaria,* the loop-like clamp-connection at the base of basidia is a typical genus character (Corner 1970). Secondary septations in basidia are found occasionally after spore discharge. Basidia maybe two-, four-, or six-spored. The size of the sterigmata varies from small to large, and in some cases, may be of indeterminate length. Sterigma may be straight to curved (as in species of *Clavulina*), and always hyaline (Thind 1961).

Hyphae

Most basidiomata of clavarioid fungi are monomitic. Dimitic hyphae (thick-walled, unbranched, and colourless skeletal hyphae along with generative hyphae) is the distinguishing feature of *Pterula* and *Pterulicium* (Senthilarasu 2013a). The hyphae of clavarioid fungi are typically hyaline or subhyaline, rarely darker in colour (Thind 1961). Corner (1950) distinguished those species with monomitic hyphae into two categories. One with normal inflation and clamp-connection as in *Ramaria, Ramariopsis, Lentaria, Clavulinopsis* and *Clavariadelphous.* The other has inflated and secondary septations without clamp-connections, like *Clavaria* and some *Clavulina* species (Thind 1961). Another peculiar type of hyphae found in some genera, such as *Lachnocladium,* is the dicophyses hyphae. It has limited growth and has thickened yellow-brown walls with many branches (Corner 1950; Perez-Moreno & Villarreal 1989). According to Corner (1950), monomitic hyphae are typically thin-walled to rarely thick-walled, as in *Lentaria* and the "Stricta group" of *Ramaria*. The genus *Clavaria* is characterized by monomitic hyphae that lack clamp-connections (Corner 1950, 1970; Petersen 1988; Olariga *et al.* 2015). In the dimitic pteruloid series of Corner (1950) clamp-connections are present. The clamp-connections are predominantly of normal shape but often show abnormal shapes and sizes. In the

subgenus *Holocoryne* of *Clavaria*, there is a wide loop-like clamp-connection at the base of the basidium (Corner 1950, 1970; Thind 1961; Petersen 1988). Broom cells are observed in the genus *Physalacria* (Dentinger & McLaughlin 2006).

Cystidia

Cystidia are sterile, hyaline, usually enlarged or modified thick-walled hymenial elements either projecting or immersed in the hymenium. In most of the clavarioid fungi, cystidia are generally absent. However, some sterile structures like cystidia, setae, caulocystidia, gloeocystidia, and oleocystidia have been described for some clavarioid fungi. *Lachnocladium* and *Clavicorona* are characterized by the presence of gloeocystidia, which are thin-walled and become thick-walled in older parts, and somewhat enlarged sterile basidia with oily contents (Thind 1961). Clavate, often capitate cystidia with oily resinous contents (oleocystidia) are found in *Physalacria,* and caulocystidia have been observed in the slender fructifications of *Clavariadelphus* and pteruloid groups (Thind 1961). Thin-walled cystidioles are observed in some species of *Pterula, Clavaria, Ramaria,* and *Clavulinopsis* (Corner 1950).

Habitat

Clavarioid fungi have been reported as mycorrhizal (Trappe 1962; Seviour *et al.* 1973; Englander and Hull 1980; Burke *et al.* 2005, 2006), saprotrophic (Rinaldi *et al.* 2008; Tedersoo *et al.* 2010), or possibly with an unknown biotrophic nutritional mode (Tedersoo *et al.* 2010). They are predominantly saprobic, with a terrestrial habit of growing on dead, decaying plant remains or in mossy grassland, while only a very few of them in the genus *Typhula* are reported as parasitic (Thind 1961). Most species with large basidiomata grow in humus. Many with simple basidiomata occur in open grasslands or in mossy places (Corner 1950). Small basidiomata of *Typhula, Pistillaria,* and *Pterula* grow on substrates like dead leaves and herbaceous stem twigs. Some species, particularly in the genera *Clavulina* and *Ramaria,* are known to be ectomycorrhizal (Englander & Hull 1980; Mueller *et al.* 1986). Genera like *Ertzia, Multiclavula, Lepidostroma,* and *Sulzbacheromyces* are lichenized and grow in association with algae. *Lentaria mucida* (Fr.) Corner and a few more are phycophilous, a peculiar and rare habitat in clavarioid fungi (Corner 1950). The

mycelium of these fungi grows in films of green or blue-green algae that cover the substratum (Corner 1950; Thind 1961).

Ultrastructural characters

Besides gross morphological characters, there are ultrastructural characters of phylogenetic significance among Basidiomycetes (Pellegrini & Patrignani 1994). Such an ultrastructure called the dolipore septal apparatus is found in certain clavarioid species (Pellegrini & Patrignani 1994; Hibbett 2014). *Clavariadulphus pistillaris* (L.) Donk, *Gomphus clavatus* (Pers.) Gray, *Ramaria sanguinea* (Pers.) Quèl., *R. flavascens* (Schaeff.) R. H. Petersen, *R. formosa*, *R. ignicolour* Corner, and the genus *Tremellodendron* exhibit dolipore septal apparatus (Pellegrini & Patrignani 1994; Hibbett 2014). In *Tremellodendron* and *Ramaria spp.* imperforate septal pore cap (SPC) are present (Hibbett 2014). Whereas, in *C. pistillaris* perforate SPC are present (Pellegrini & Patrignani 1994).

Molecular characters

The phylogenetic relationships of the heterogeneous group of clavarioid fungi are extremely difficult to resolve (Pine *et al.* 1999). Clavarioid fungi are a conspicuous group in the phylogeny of higher basidiomycetes (Petersen 1971b; McAfee & Grund 1982). The most commonly used gene regions for sequencing clavarioid fungi at the species level are the internal transcribed spacer (ITS) and 28S, nuclear ribosomal large subunit (nrLSU). Other gene regions such as RNA polymerase II subunits rpb1 and rpb2, mitochondrial SSU (mtSSU rDNA), and EF-1α are infrequently used in the clavarioid group (Pine *et al.* 1999; Henkel *et al.* 2011; Uehling *et al.* 2012; Olariaga *et al*. 2015, 2020; Kautmanová 2012a, 2012b; Dentinger & McLaughlin 2006; Maneevun & Sanoamuang 2010; García–Sandoval *et al*. 2005; Petersen *et al*. 2014; Birkebak *et al.* 2013). However, for certain genera, specific gene regions are more accurate than other gene regions. For example, in the genus *Clavaria,* ITS sequences are found to be more effective in the phylogenetic analyses (Olariaga *et al.* 2015).

2.3. ECOLOGICAL AND ECONOMIC IMPORTANCE

Clavarioid fungi are mostly saprotrophic with terrestrial habitats. They grow generally in woodland leaf litter, with a few on decayed wood **(**Mueller *et al.* 1986; Corner 1950, 1970; Olariaga *et al.* 2015). They also play an important ecological role as symbionts and are ectomycorrhizal. Some species of *Ramaria,* such as *R. aurea* (Schaeff.) Quel., *R. botrytis* (Pers.) Bourdot, and *R. formosa* (Pers.) Quel., form mycorrhizae with certain plant species (Trappe 1962; Knudsen 2012). The genus *Clavulina* is reported as lignicolous (Corner 1950). Certain species in the genus *Clavulina* produce lignocellulolytic enzymes that are important for the decomposition of plant material (Osono 2007). Some clavarioid fungi are reported as pathogenic. For example, a few species of the genus *Typhula* are facultative plant pathogens, causing "snow molds" or "Typhula blight" disease (Knudsen 1997; Matsumoto *et al.* 2001; Hoshino *et al.* 2008, 2009). *Pterulicium xylogenum* (Berk. & Broome) Corner that causes culm rot disease in bamboo (Munkacsi *et al.* 2004; Harsh *et al.* 2005). *Pterulicium echo* and *Myrmecopterula* exhibit ant-fungal mutualism (Munkacsi *et al.* 2004; Leal- Dutrra *et al.* 2020). *C. zollingeri* Lev. grows in nutrient-poor semi-natural grasslands, frequently on acidic soil. Hence, it is used as an indicator species to assess the fungal diversity of nutrient-poor grasslands in Ireland (Mitchel 2000).

Clavarioid fungi are economically important due to their edibility, medicinal properties, and pathogenicity. They have a lot of therapeutic and nutritional importance due to their valuable components (Elkhateeb *et al.* 2021). The neutraceutical and bioactive potential of coral fungi have been extensively reported from the genus *Ramaria* (Sharma & Gautam 2017; Vidović *et al.* 2014; Acharya *et al.* 2017b; Aprotosoaie *et al.* 2017; Barros *et al.* 2008; Aldred 2008; Dattaraj *et al.* 2020). Many *Ramaria* species are a rich source of bioactive secondary metabolites (Gursoy *et al.* 2010; Gezer 2006; Liu *et al.* 2013; Aprotosoaie *et al.* 2017; Toledo *et al.* 2016; Ramesh & Pattar 2010; Acharya *et al.* 2017b; Khatua *et al.* 2015), and has proven antioxident, antibacterial, anticancerous and antifungal properties (Kim & Lee 2003; Gursoy *et al.* 2010; Ramesh & Pattar 2010; Gezer 2006; Liu *et al.* 2013; Barros *et al.* 2008; Sharma & Gautam 2017; Acharya 2017; Han *et al.* 2017; Bala *et al.* 2011;

Rai *et al.* 2013; Zhang *et al.* 2015; Yoo *et al.* 1982; Chung 1979; Kim *et al.* 1999; Zhou 2017; Sadi *et al.* 2016; Gao *et al.* 2012; Dong *et al.* 2020). Certain species of the genera *Clavaria, Clavulina, Clavulinopsis,* and *Pterula* also exhibit antioxident, antibacterial, anticancerous, anti-fungal, anti-proliferative, immunostimulatory and anti-inflammatory activities (Deo *et al.* 2019; Agrahar & Subbulakshmi 2005; Spiteller 2015; Engler & Anke 1995; Engler *et al.* 1999; Wasser 2002; Sharma & Gautam 2017). Several species of the genera *Clavaria, Clavulinopsis, Ramaria,* and *Ramariopsis* are edible (Sharma & Gautam 2017; Adhikari 2005; Christensen *et al.* 2008; Wu *et al.* 2019; Gonzalez-Avila *et al.* 2013a; Acharya 2016; Thu *et al.* 2020; Debnath *et al.* 2019; Khaund & Joshi 2014; Firdaus *et al.* 2016; Deo *et al.* 2019; Njue *et al.* 2017).

2.4. DISTRIBUTION

Clavarioid fungi have a worldwide distribution. They are reported from different parts of the world. AFRICA: (Corner 1950, 1967; Christan & Yorou 2009; Daniëls *et al.* 2012), Cameroon (Roberts 1999), Canary Island (Corner 1970), Ethiopia (Gminder *et al.* 2020), Jamaica (Corner 1970), Madagaskar (Duhem & Buyck 2007), New Guinea, Congo, Uganda (Corner 1950). ANTARTICA: (Yajima *et al.* 2017). ASIA: Azerbaijan (Mustafabayli *et al.* 2021), Bangladesh (Marzana *et al.* 2018); Ceylon (Corner 1968); Colombia (Corner 1970); China (Zang *et al*. 2010*;* He *et al*. 2016; Wu *et al.* 2019; Tan & Zhao 2020*),* Indonesia (Arko *et al.* 2017), Japan (Lyimo *et al.* 2012; Corner 1950; Corner 1966; Matsumoto & Tajimi 1993; Ikeda *et al.* 2015, 2016, 2017; Hoshino *et al*. 2009; Kasuya *et al.* 2016); Java (Firdaus *et al.* 2016), Iran (Saber 1989), Malasia (Corner 1950, 1967; Lee *et al*. 2008; Lang *et al.* 2006; Chen *et al*. 2006; Hamzah & Mohammad 2021), Korea (Kim *et al*. 2020), Nepal *(*Christensen 2008), Philippine (Corner 1950), Uzbekistan (Gafforov & Hoshino 2015), Pakistan (Nasim *et al.* 2008; Hanif *et al.* 2019), Tibet (Wang *et al.* 2015), Thailand (Maneevum & Sanoamuang 2010; Christan & Hampe 2013), Turkey (Kaygusuz & Çolak 2017; Işik 2020). AUSTRALIA: (Petersen 1979; Young & Fechner 2009; Young 2014), Czech Republic (Jindrich & Antonin 2005), Holland (Corner 1950; 1967), New Zealand (Petersen 1988), The Solomon Islands (Corner 1950; 1967), Tasmania

(Corner 1950). EUROPE: (Domański 1984; Jülich 1984, 1985; Krieglsteiner 2000; Roberts 2007; Corner 1950, 1967; Shiryaev 2009a,b; Kautmanová *et al.* 2012b; Petersen 1999), Czechoslovakia (Corner 1970), Estonia (Shiryaev 2009b), Finland (Panu *et al.* 2016), England (Edwards *et al.* 2014; Corner 1950), Faroe Island (Hoshino *et al.* 2004), Fennoscandia (Bendiksen *et al.* 2015), France (Corner 1950; 1967), Germany (Engler *et al*. 1995; Engler *et al*. 1999), Holland (Corner 1950; 1967), Iberian Peninsula (Olariaga & Salcedo, 2012), Iceland (Hoshino *et al.* 2004), Ireland (Corner 1970), Italy (Agnello & Baglivo 2011), Norway (Matsumoto & Tronsmo 1995), Netherlands, Belgium (Geesink & Bas 1992), Poland (Błonski 1890; Kowalski & Bilański 2021; Wojewoda 1974, 2003; Guminska 1976, 1981; Kujawa & Gierczyk 2013; Nowicki & Gierczyk 2013a, b; Halama *et al.* 2017), Romania (Aprotosoaie *et al.* 2017), Russia (Sidorova & Velikanov 1998; Volobuev 2020), Spain, Sweden (Olariaga *et al* 2016; Corner 1950), Scotland (Corner 1950). NORTH AMERICA: (Burt 1922), United States of America, Arknas (Hughes *et al.* 2014), Alaska (Corner 1970), Canada (Coker 1923), Costa Rica, Dominica (Corner 1950), Guatemala, Bolivia (Corner 1970), Guadeloupe (Corner 1950), Minnesota, (Knudsen 2012), Mexico (Pérez-Moreno & Villarreal 1989), Nova Scotia (McAfee & Grund 1982), Panama (Welden 1966), Western Washington (Marr & Stuntz 1973), Oregon (Corner 1950), Pacific Northwest (Bruehl & BM 1975), Trinidad (McLaughlin & McLaughlin 1980. SOUTH AMERICA: Argentina (Corner 1970); Brazil (Felipe 2012; Furtado *et al*. 2016; Corner 1966; Leal-Dutra *et al.* 2020), Bolivia (Corner 1948), Ecuador (Corner 1950), Guyana (Corner 1950; Thacker & Henkal 2004; Henkel *et al.* 2005; Henkal *et al.* 2011; Uehling *et al.* 2012), Peru (Corner 1948).

The earliest available records of clavarioid fungi from India are those of Leveille (1844), Berkeley (1856), Banerjee & Ganguli (1945), Banerjee (1947), Ramakrishnan & Subramanian (1952),Thind (1956a, 1956b, 1957a 1957b, 1961), Thind & Sukh Dev (1956), Thind & Anand (1956), Thind & Raswan (1958), Butler & Bisby (1931), Ahmad (1949), Parndekar (1964), Thind & Rattan (1967), Thite *et al.* (1976), Patil & Thite (1977), Sharma & Munjal (1977), Sharma & Janadaik (1978), Khurana (1980), Thind & Sharda (1985), Methven (1989), Das (2009), Dehariya *et al.* (2010), Ramesh

and Pattar (2010), Pushpa & Purushothama (2012), Senthilarasu (2013a, 2013b), Tiwari *et al.* (2013), Das *et al*. (2016), Verma & Pandro (2018) and Das *et al.* (2020).

The published reports of clavarioid fungi from Kerala are by Mohanan (2011) and Krishnapriya & Kumar (2021) (Table 2).

TABLE 2. Clavarioid taxa previously reported from Kerala.

Sl. No.	Taxa	Family	References
1	*Clavaria cystidiata*	Clavariaceae	Krishnapriya & Kumar (2021)
2	*C. zollingeri*	Clavariaceae	Mohanan (2011)
3	*Clavulinopsis aurantiocinnabarina*	Clavariaceae	Mohanan (2011)
4	*C. corniculata*	Clavariaceae	Mohanan (2011)
5	*C. dichotoma*	Clavariaceae	Mohanan (2011)
6	*C. fusiformis*	Clavariaceae	Mohanan (2011)
7	*C. laeticolor*	Clavariaceae	Mohanan (2011)
8	*C. luteoalba*	Clavariaceae	Mohanan (2011)
9	*Ramariopsis kunzei*	Clavariaceae	Mohanan (2011)
10	*R. pulchella*	Clavariaceae	Mohanan (2011)
11	*Clavulina cristata*	Hydnaceae	Mohanan (2011)
12	*C. rugosa*	Hydnaceae	Mohanan (2011)
13	*Ramaria apiculata*	Gomphaceae	Mohanan (2011)
14	*R. cokeri*	Gomphaceae	Mohanan (2011)
15	*R. eumorpha*	Gomphaceae	Mohanan (2011)
16	*R. flava*	Gomphaceae	Mohanan (2011)
17	*R. gracilis*	Gomphaceae	Mohanan (2011)
18	*R. formosa*	Gomphaceae	Mohanan (2011)
19	*R. pallida*	Gomphaceae	Mohanan (2011)
20	*R. versatilis*	Gomphaceae	Mohanan (2011)

2.5. ORDER AGARICALES Underwood

Agaricales, established by Underwood (1899), is the largest group of mushrooms- forming fungi in Agaricomycetes. The order comprises of 13,000 described species in 300 genera and 26 families (Kirk *et al*. 2008). The order includes more than half of all known species of the homobasidiomycetes (Hibbett *et al.* 1997; Hibbett & Thorn 2001; Matheny *et al.* 2006). Agaricales species are cosmopolitan, found in deserts, forests, grasslands, tundra, and tropical, temperate, and alpine tundra (Matheny *et al.* 2006). Most of the members are terrestrial, lignicolous, and saprobic, and many are mycorrhizal (Alexopoulos *et al.* 1966; Zhao *et al.* 2008) with the roots of vascular plants. They are rarely found associated with unicellular green algae, cyanobacteria and lichens, and few are bryophyte associates. Traditionally, Agaricales were grouped based on the presence of gills and mushroom-shaped fruiting bodies (*Agaricus* L., *Amanita* Pers., *Entoloma* (Fr.) P. Kumm., *Hygrophorus* Fr.). But now, the classification is more specific based on their genetic relatedness, and thus they may or may not have gills, and basidiomata may or may not be mushroom-shaped (such as *Clavaria* Vaill. ex L., *Pterula* Fr., *Schizophyllum* Fr., *Typhula* (Pers.) Fr.). Taxa with clavarioid and simple club-shaped basidiomata are also included in the order (Matheny *et al*. 2006). The order Agaricales is characterized by members with fleshy basidiocarps that are typically monomitic, rarely dimitic (Acharya *et al.* 2010), non-septate basidia, lack of stichobasidia, absence of spinose hymenophores, lack of heteromerous trama, or a combination of a laticiferous hyphal system with amyloid, ornamented spores (Kuhner 1980; Matheny *et al.* 2007).

In 1874, Fries classified 12 genera of gilled mushrooms (*Agaricus*) based on macroscopic features such as basidiocarp type and spore print colour. Later, in 1889, Fayod recognized 108 genera based on microscopic features (Matheny *et al*. 2006; Zhao *et al.* 2008). Kühner (1980) studied the use of cytological characters in his classification. He introduced a broad generic concept and listed 75 genera in five orders: Tricholomatales (including some gilled taxa of the Polyporales), Agaricales *s. str.*, Pluteales, Russulales, and Boletales (Matheny *et al.* 2006). The significant revision in agarics was done by Singer (1986), in his work "The Agaricales in Modern

Taxonomy". Singer provides a detailed concept of the order Agaricales in this work. In this work Singer used anatomic and macroscopic characters for defining the limits of genera and families. Singer had included gilled mushrooms along with taxa of the Boletales, Russulales, and Polyporales (Matheny *et al.* 2006). In his concept, the term Agaricales contains the type genus *Agaricus* and type family Agaricaceae. According to Singer, three major groups in the order Agaricales could be recognized: Agaricales *sensu stricto,* Boletales, and Russulales. (Singer1986). A total of 18 families and 230 genera were distinguished in his system of classification (Matheny *et al.* 2006; Zhao *et al.* 2008). Later, these 3 groups found support as the euagaric clades, the bolete clade and the russuloid clade based on molecular data (Hibbett & Thorn 2001).

Earlier works had heavily relied on spore print colour, basidiomatal formation pattern, and anatomical and cytological traits for defining Agaricales (Matheny *et al.* 2006). Later molecular phylogenetic studies in Agaricales resolved the many taxonomic uncertainities of this group, accepting some earlier concepts while rejecting others. Hibbett *et al.* (1997, 2004) conducted a phylogenetic study using nuclear and mitochondrial ribosomal DNA sequences of the representatives of the Agaricales, Aphyllophorales, and "Gasteromycete" families (i.e., gilled, nongilled, and puffballs), thereby suggesting that morphological characters such as basidiomatal form and hymenophore type have been phylogenetically misleading. Moncalvo *et al.* (2000) analyzed the nuclear large subunit ribosomal DNA sequences of the order Agaricales, and examined the phylogenetic relationships within the order. He revealed that many families and genera of agarics were not monophyletic and that ecological traits have not been used in the diagnosis of natural groups.

A phylogenetic study of Moncalvo *et al.* (2006) using nuclear large subunit ribosomal DNA sequences revealed that 117 monophyletic clades can be recognized in the euagaric clade. In that study many traditional taxonomic groupings were proved to be artificial. Later phylogenetic studies (Peintner *et al.* 2001; Binder & Bresinsky 2002; Binder *et al.* 2002; Hallen *et al.* 2003; Bodensteiner *et al.* 2004; Larsson *et al.* 2004; Binder *et al.* 2005; Matheny & Bougher 2006) gave a better understanding

about the evolutionary relationships with non-gilled basidiomycetes members of the Agaricales.

A phylogenetic treatment of the Agaricales by Matheny *et al.* (2006) using a DNA sequence dataset of 6 gene regions (rpb1, rpb-intron 2, rpb2, 18S, 25S, and 5.8S rRNAs) from 146 genera and 238 species revealed six distinct clades (agaricoid, tricholomatoid, marasmioid, pluteoid, hygrophoroid, and plicaturopsidoid). The study recognized 30 families, four unplaced tribes, and two informally named clades distributed in the six clades (Table 3).

TABLE 3: Major clade of Agaricales recognized by Matheny *et al.* (2006).

Clades	Families
Plicaturopsidoid clade	Macrocystidiaceae, Atheliaceae, Clavariaceae
Pluteoid clade	Pluteaceae, Amanitaceae, Pleurotaceae and Limnoperdonaceae
Hygrophoroid clade	Hygrophoraceae, Pterulaceae, Typhulaceae
Marasmioid clade	Omphalotaceae, Marasmiaceae, Cyphellaceae, Physalacriaceae, Schizophyllaceae, Lachnellaceae
Tricholomatoid clade	Lyophyllaceae, Entolomataceae, Tricholomataceae, Mycenaceae
Agaricoid clade	Strophariaceae, Hymenogastraceae, Inocybaceae, Crepidotaceae, Cortinariaceae, Bolbitiaceae, Psathyrellaceae, Hydnangiaceae, Agaricaceae, Nidulariaceae

Clavariaceae Chevallier

The family Clavariaceae was established by the French botanist Francois Fulgis Chevallier (1826). All genera containing species that resemble aquatic coral-like basidiomata were placed in the family Clavariaceae. Many monographs and floras were introduced (Muller 1780; Holmskjold 1790; Persoon 1797b, c; Fries 1821; Peck 1894; Atkinson 1909), which included all the sparingly described clavarioid species within the family Clavariaceae. Later, Donk (1964) and Corner (1950) realized that, in a broad sense, the family was not a natural phylogenetic assemblage of related

species. Corner published his world monograph in 1950 (revised in 1967 and updated in 1970), which critically revised all the recognized taxa, and created a new classification, introducing the modern concepts of many genera of clavarioid fungi.

The family Clavariaceae is comprised of a variety of basidiomatal structures, including pendant-hydnoid, cylindrical, clavate, coralloid, resupinate, and lamellate-stipitate basidiomata (Birkebak *et al.* 2013). The members of this family are characterized by monomitic generative hyphae, with or without clamp-connections, the absence of cystidia, smooth to ornamented, thin- to thick-walled basidiospores, and basidiomatal colours that range from white to yellowish, orangish, brown, pink, violet to black (Thind 1961; Corner 1970; Kautmanová *et al.* 2012). Corner (1950) included three genera (*Clavaria* Vaill., *Clavulinopsis* Overeem, and *Ramariopsis* (Donk) Corner) in his original concept of the Clavariaceae. Based on the molecular phylogenetic studies by Pine *et al.* (1999), Clavariaceae was first shown to have affinities with Agaricales (Birkebak *et al.* 2013). Currently, the family Clavariaceae consists of seven genera. They are *Clavaria*, *Clavulinopsis*, *Camarophyllopsis* Herink, *Clavicorona* Doty, *Hyphodontiella* A Strid, *Ramariopsis*, and *Mucronella* Fr. (Larrson *et al.* 2004; Dentinger & McLaughlin 2006; Matheny *et al.* 2006; Larsson 2007; Birkebak *et al.* 2013).

Genus *Clavaria* Vaillant

Clavaria is one of the largest genera in the family Clavariaceae, with *Clavaria fragilis* Holmsk. as the type species. The genus comprising of about 200 species recorded worldwide (www.indexfungorum.org, accessed on 15 December 2022; Roskov *et al.* 2020). The members produce club to cylindrical or coralloid basidiomata. Basidiomata vary in colour from white to yellow, orange, pink, brown, or black (Corner 1950). They are distributed throughout the temperate, tropical, and boreal areas of the world (Corner 1950; Olariaga *et al.* 2015). Secondarily septate tramal hyphae that lack clamp-connections, simple-septate basidia with loop-like basal clamp-connection, and generally smooth, hyaline, subglobose to cylindrical or ellipsoid basidiospores are the characteristic features of the genus *Clavaria* (Corner 1950).

It was Vaillant (1727) who first introduced the genus name *Clavaria*. *Clavaria* was used as one of the original genera by Linneaus in his *Species Plantarum* (1753), which included all the species of fungi with club- or coral-shaped sexual structures. Although the name *Clavaria* had also been used for a group of red algae by Stackhouse (1816), proposals by Doty (1948a), Donk (1949) and Rogers (1950) attributed it a conserved status.

In the 18th and 19th centuries, the name *Clavaria,* introduced in floras and comprehensive monographs such as those of Scopoli & Antonio (1772), Muller (1780), Holmskjold (1790), Persoon (1797a, b), Saccardo (1888), Pattouillard & Gaillard (1888), Massee (1895), Peck (1894), Persoon (1801, 1822), were purely based on macroscopic characters such as habit, habitat, and branching pattern. In the 20th century, several monographic treatments of *Clavaria,* like those of Coker (1923, 1947), Burt (1922), Kauffmann (1927), Doty (1948b), and Donk (1933), were published based on the study of microscopic structures.

The first and largest publication on clavarias was by Coker (1923). It was exclusively from the United States and Canada. Besides extreme differences in size, texture, method of branching, and colour, spore features were also considered as reliable characters. Later, in 1950, Corner published a monograph of clavarioid fungi from the tropics, in which he critically revised all the taxa and introduced a modern concept of the genus *Clavaria*. In that, Corner restricted the genus concept to include only those members having inflated, contextual hyphae without clamp-connections. In 1970, Corner published a supplement to the monograph of *Clavaria* and allied genera. The genus concept of Corner in the monograph (1950) and the supplement to this monograph (1970) was agreeable to Petersen's (1966, 1967b, 1967c, 1978c) concept based on Petersen's studies on collections from temperate regions.

Corner (1970), in his supplement to the monograph of clavarioid fungi, classified the genus *Clavaria* into two subgenera: *Clavaria* and *Holocoryne*. All the *Clavaria* species without clamp-connections were kept under the subgenus *Clavaria,* and those with loop-like clamp-connections at the base of basidia were kept under the

subgenus *Holocoryne*. Whereas, Petersen (1988) recognized three subgenera in *Clavaria*: *Clavaria, Clavulinopsis,* and *Holocoryne*. His system of classification is based on the presence, absence, and location of clamp-connections like that of Corner (1970). According to Petersen's (1988) classification, basidia without clamp-connection were kept in the subgenus *Clavaria*, basidia with loop-like clamp-connection were included in the subgenus *Holocoryne,* and those with clamp-connections on both hyphae and basidia were placed in the subgenus *Clavulinopsis.*

When the genus *Clavaria* Vaill. was proposed, it included all the fleshy fungi placed in a highly polyphyletic order, the Aphyllophorales (Rea 1992). Later, by assembling the taxa, the genus was gradually trimmed down to many species (Birkebak *et al.* 2013). Pine *et al.* (1999) disagree with Corner's *Clavaria* theory, which suggests that a simple club-producing form is the ancestral state of fleshy fungi. Pine *et al.* (1999) concluded in their phylogenetic study that *Clavaria* appears to be derived from the monophyletic lineage that contains most of the gilled fungi. Although Birkebak *et al.* (2013) considered *Clavaria* as paraphyletic did not reject the monophyly of *Clavaria* proposed by Pine *et al.* (1999). The phylogenetic analysis based on DNA sequences of the LSU region of *Clavaria* species with dark basidiomata (Kautmanová *et al.* 2012) does not support the subgenus *Holocoryne* by Corner (1950). A molecular study by Olariaga *et al.* (2015) supports the monophyly of subgenus *Clavaria* but rejects the monophyly of subgenus *Holocoryne*. Olariaga *et al.* (2015) support the views of Corner's *Clavaria* theory, and suggest that "agaricoid basidiomata have evolved within the clavarioid *Clavaria* lineage."

Taxonomic characters

Basidiomata are generally simple or rarely branched, solitary, caespitose, or in gregarious clusters. Basidiomata may be small clubs or large coral-like structures, typically smooth and brittle, sometimes with striations or grooves. Branches are radial, stem either distinct or indistinct (Thind 1961). One of the basic identifying characteristics of *Clavaria* species is the colour of the basidiomata (Kautmanová *et al.* 2012). Colours range from white to grey or brown, with a few exceptions of yellowish, pink, reddish, purple, violet, or grey (Corner 1950, 1970; Thind 1961).

Basidia are mostly four-spored, in some species two-spored (*C. acuta* Sowerby, *C. fuscata* Oudem.), with or without wide, open, loop-like basal clamp-connection (Corner 1950, 1970; Thind 1961; Petersen 1978). Spores are generally smooth, rarely rough to asperulate, subglobose to cylindric, ellipsoid, thin-walled, white or yellowish to brown or hyaline, generally aguttulate or finely guttulate or with granular contents. Hyphae are always monomitic, thin-walled, and inflated. Hyphae lack clamp-connections and are generally secondarily septate but not agglutinated (Corner 1950; Thind 1961; Olariaga *et al.* 2015).

Ecological and economic importance

Most members of this genus are saprotrophic, decomposing leaf litter and other organic materials on the forest floor (Mueller *et al.* 1986; Olariaga *et al.* 2015). Certain species such as *C. fragilis Holmsk.* and *C. argillacea* Pers. have been reported to exhibit biotrophic association with the species of Ericaceae (Seviour *et al.* 1973; Englander & Hull 1980; Birkebak *et al.* 2013). *C. zollingeri* Lev. is often encountered in nutrient-poor acidic soil and hence are considered as indicators of certain soil types (Mitchel 2000). Some species (*Multiclavula mucida* (Pers.) R.H. Petersen and *M. vernalis* (Schwein.) R.H. Petersen) are associated with soil algae (Thind 1961; Pat & Ed Grey 2018).

Clavaria fragilis and *C. vermicularis* Batsch are traditionally used by the native people of the Northwestern Himalayan regions for culinary purposes since ancient times and are known for their low-fat content (Sharma & Gautam 2017). Some species of this genus (*C. fragilis, C. coralloides* L., *C. vermicularis, C. amoena* Zoll. & Moritzi, and *C. rosea* Dalman*)* show antimicrobial activities, and some are high in antioxidant activity due to the presence of higher phenolic compounds like β-carotene, lycopene, ascorbic acids, anthocyanidins, and tocopherol (Kumar Sharma & Gautam 2017).

Distribution

The genus *Clavaria* is cosmopolitan in distribution. AFRICA (Corner 1950, 1967), Cameroon (Roberts 1999). ASIA: Malasia, Indonesia (Corner 1950, 1967),

India (Butler & Bisby 1931; Uttarakhand Thind & Sukh Dev 1956; Thind & Anand 1956; Thind 1961; Darjeeling Thind & Rattan 1967; Sharma & Munjal 1977; Kerala Mohanan 2011; Himachal Pradesh Sharma & Gautam 2017; Krishnapriya & T.K.A. Kumar 2020), China (Yan *et al.* 2020, 2022), Japan (Corner 1950; Lyimo *et al.* 2012), Thailand (Maneevum & Sanoamuang 2010). AUSTRALIA: (Furtado *et al.* 2016), New Zealand (Petersen 1988), The Solomon Islands (Corner 1950, 1967). EUROPE: (Corner 1950, 1967; Roberts 2007; Kautmanova *et al*. 2012b), Belgium (Geesink & Bas 1992), Estonia (Shiryaev 2009b), Finland (Panu *et al*. 2016), France (Corner 1950; 1967), Holland (Corner 1950; 1967), Italy (Agnello & Baglivo 2011), Netherlands (Geesink & Bas 1992). NORTH AMERICA: (Burt 1922), Canada (Coker 1923), Costa Rica (Corner 1967), Nova Scotia (McAfee & Grund 1982). SOUTH AMERICA: Brazil (Furtado *et al.* 2016).

Genus *Clavulinopsis* Overeem

Clavulinopsis is a genus of coral fungi in the family Clavariaceae, currently composed of 84 species (www.indexfungorum.org, accessed on 07 August 2022). Basidiomata are simple, branched, or coralloid. The colour of the basidiomata may be white, yellow, orange, rarely brown, red, grey, or purple (Corner 1950; Keles 2021). Basidiomata may be solitary, gregarious, or caespitose. Monomitic, mostly inflated hyphae with clamp-connections, smooth to rarely echinulate spores that are globose, pip-shaped, or ellipsoid, and basidia with basal clamp-connection are the distinguishing microscopic characters of the genus *Clavulinopsis* (Petersen 1968a; Knudsen & Vesterholt 2018; Keles 2021). *Clavulinopsis* differs from *Clavaria* by having less brittle basidiomata and by the presence of normal basidial and hyphal clamp-connections. (Corner 1950; Thind 1961; Petersen 1978a).

The genus *Clavulinopsis* was first introduced by Van Overeem in 1923 for his species *C. sulcata* Overeem (Keles 2021). Donk (1933) considered *Clavulinopsis* a synonym for the genus *Clavulina.* Doty (1948a) accepted the genus *Clavaulinopsis* with *C. sulcata* as the type (McAfee and Grund 1982). Later, when Corner (1950) introduced his monograph of clavaroid fungi, *Clavuniposis* was one of the four genera in the series *Clavaria*. He classified the genus into seven groups based on the shape

and ornamentation of the basidiospores and the colour of the basidiomata. Petersen (1968), in his monographic treatment of ten North American species, discusses the generic delimitation in a general way. He used the shape of the basidiospores, the hyphal clamp-connections, and the colour of the basidiomata as key characters. Corner (1970) reorganized the genus *Clavulinopsis* in to three subgenera (*Acularia, Clavulinopsis,* and *Paraclavaria*). The subgenus *Clavulinopsis* was again grouped into two sections: *Clavulinopsis* and *Cornicularia*, based on the length of the apiculus. Petersen (1978a) placed the genus *Clavulinopsis* as the subgenus of *Clavaria*.

Based on the phylogenetic studies by Pine *et al.* (1999), *Clavulinopsis* was found to be derived from the lineage that contains most of the gilled fungi. Petersen (1968a, 1971b) reported grey-green macrochemical reactions with iron salt in some species of *Clavulinopsis* (which were later transferred to the genus *Ramariopsis* by Petersen 1978a), which is a characteristic feature of the members of the Gomphaceae family (Pine *et al*. 1999; Giachini *et al.* 2010). Later, Petersen (1978a) reported that the pigment pistillarin is responsible for the green colour reaction in the family Gomphaceae, which was absent in *Clavulinopsis* (Pine *et al.* 1999). Phylogenetic analysis by Pine *et al*. (1999) does not support the placement of *Clavulinopsis* in the family Gomphaceae. Dentinger & McLaughlin (2006) included the type of *Clavulinopsis*, *C. sulcata* in their phylogenetic analysis and recovered a highly supported monophyletic Clavariaceae. Their study supports Corner's view of accepting *Clavulinopsis* at the generic level (Dentinger & McLaughlin 2006). This view was also supported by Birkebak *et al.* (2013). Birkebak's systematic studies on the family Clavariaceae recovered *Clavulinopsis* as one of the seven genera within the family. Systematic studies on the family Clavariaceae by Kautmanová *et al*. (2012) disapprove the delimitation of *Clavulinopsis* by Corner (1950). The *Clavulinopsis* species with basidiospores having prominent hilar appendage (in Corner's classification) appeared to be more closely related to the genus *Ramariopsis* in phylogenetic studies. From the point of view of Kautmanová *et al*. (2012), the classification introduced by Petersen (1978) seems to be more reliable.

Taxonomic characters

Basidiomata are simple or branched. White, yellow, orange, brown, red, grey, or purple (Keles 2021) basidiomata are produced. Branching is radial. Basidiospores are white or tinged yellow, smooth or, in a few species echinulate, globose, pip-shaped, or ellipsoid, usually with a large oildroplet, sometimes multiguttulate. Basidia are clavate with basal clamp-connection, sterigmata are mostly four, occasionally two to three. In some species with branched basidioamata, the hymenium is restricted towards the apex. Subhymenial hyphae are short-celled, generally inflated. Hymenium is composed of thin- to slightly thick-walled monomitic hyphae, often interwoven with narrow and inflated hyphae. Cystidia are absent except for *C. luticola* Lasch. Hyphal clamp-connections are always present (Corner 1950; Thind 1961; Petersen 1968; Knudsen & Vesterholt 2018; Keles 2021).

Ecological and economic importance

Generally, species are terrestrial and exceptionally lignicolous (Corner 1950; Thind 1961; Petersen 1968a; Kirk *et al.* 2008). *C. fusiformis* (Sowerby) Corner is used for culinary purposes (Adhikari 2005; Christensen *et al.* 2008). Certain *Clavulinopsis* species have been reported to contain antitumor or immunostimulating polysaccharides (Wasser 2002). Anti-B red blood cell agglutinin was reported from the extract of *C. fusiformis* (Furukawa *et al.* 1995). A new amino acid, d, l-2-amino-3(cis), 5-hexadienoic acid, was isolated from the basidiomata of *C. helvola* (Pers.) Corner (Aoyagi 1997).

Distribution

The genus Clavulinopsis is cosmopolitan in distribution. AFRICA: Jamaica (Corner 1970). ASIA: China (Zhang *et al.* 2010); Ceylon (Corner 1968); Nepal (Christensen *et al.* 2008); Malasia (Lee *et al*. 2008); Iran (Saber 1989); India (Thind 1961), West Bengal (Acharya *et al.* 2017a), Kerala (Mohanan 2011); Japan (Corner 1966a). AUSTRALIA (Petersen 1979); Czech Republic (Jindrich & Antonin 2005), Solomn Island (Corner 1970). EUROPE (Shiryaev 2009b; Petersen 1999), Canary Island (Corner 1970); Czechoslovakia (Corner 1970); North Ireland (Corner 1970).

NORTH AMERICA: Alaska (Corner 1970), Costa Rica, Guatemala, Bolivia (Corner 1970), Canada (Coker 1923, Nova Scotia (McAfee & Grund 1982), Panama (Welden 1966), USA (Coker 1923). SOUTH AMERICA: Argentina (Corner 1970); Brazil (Corner 1966a; Furtado *et al*. 2016); Bolivia (Corner 1948); Colombia (Corner 1970); Peru (Corner 1948).

Genus *Ramariopsis* (Donk) Corner

Ramariopsis is a genus in the family Clavariaceae, comprised of 49 species (www.indexfungorum.org, accessed on 01 December 2022). Basidiomata are generally small, branched or unbranched, and have a distinct stalk. Colour ranges from white, orange, cinnamon, ochraceous, purple to lavender (Corner 1950; Petersen 1978; Halama *et al*. 2017). The members are distinguished by echinulate or verrucose spores with cyanophilous ornamentation, by the presence of clamp-connections at the base of basidia and hyphae, and by the lack of inflated hyphae (Corner 1970; Knudsen & Shiryaev 2012; Halama *et al*. 2017).

The name *Ramariopsis* was introduced by Donk (1933) as a subgenus of *Clavaria* by placing *Clavaria kunzei* Fr. as the type specimen. The name *Ramariopsis* refers to its macromorphological similarities with the genus *Ramaria* (Donk 1954; Garcia-Sandoval *et al.* 2005). According to Donk's concept, small, branched basidiomata with a distinct stalk and small, hyaline, spherical to ellipsoid, echinulate, or verruculose spores were characteristic of the group. Later in 1950, Corner promoted the subgenus to the generic level. He included several fibulate species with branched, whitish basidiomes, monomitic hyphal systems, and echinulate spores in the genus and retained the type specimen *C. kunzei* as *Ramariopsis kunzei*. There were about 10 species in Corner's (1950) classification of the genus *Ramariopsis* (Garcia-Sandoval *et al*. 2005). Petersen (1966) altered the original delimitation of the genus to include smooth-spored taxa. According to Petersen, the major characteristic features of the genus include the size of the basidia, thickness of the spore wall, ornamentation, and colour of the basidiomata. He classified the genus *Ramariopsis* into two subgenera based on the ornamentation of the spores. They are subgenus *Laevispora* with smooth spores and subgenus *Ramariopsis* with echinulate spores (Garcia-Sandoval *et al.*

2005). Corner (1970), in his supplement to the monograph of clavarioid fungi, maintained the original circumscription of the genus, recognising that it links *Clavulinopsis* with *Scytinopogon*. In his concept, the genus *Ramariopsis* is closely related to *Clavulinopsis* and *Scytinopogon*. Petersen (1978b) transferred species with globose spores and conspicous hilar appendix from *Clavuliopsis* to *Ramariopsis*. Pegler and Young (1985) used electron microscopic techniques and reported that the spores were ornamented at the ultra-structural level. Based on this, they divided the genus *Ramariopsis* into three groups: the *Kunzei* group with discontinuous tunica that form verrucae; the *Biformis* group with continuous tunica that form verrucae; and the *Minutula* group with continuous tunica that gives rugose appearance (Garcia-Sandoval *et al.* 2005).

Different generic and infrageneric concepts of *Ramariopsis* and allied taxa were presented by various authors during this time period (Jülich 1984, 1985; Hansen & Knudsen 1997; Krieglsteiner 2000; Olariaga & Salcedo 2012). Based on nomenclatural arguments, Jülich (1985) transferred all the *Ramariopsis* species to *Clavulinopsis*. The genus *Ramariopsis* was included in the majority of Clavariaceae family treatments (Donk 1964; Corner 1970; Jülich 1981; Hawksworth *et al*. 1995). Petersen (1978, 1988) and Kirk *et al*. (2001) placed *Ramariopsis* in the family Gomphaceae, but this was rejected by Villegas *et al.* (1999) based on the molecular phylogenetic study of the family Gomphaceae. Molecular studies by Dentinger & McLaughlin (2006) supported the previous studies that included *Ramariopsis* in the family Clavariaceae. In their study, the genus *Ramariopsis* formed a sister group to *Clavaria*. The most important works at the species level are those by Kautmanová *et al.* (2012) and Birkebak *et al*. (2013). Both their studies strongly support the placement of genus *Ramariopsis* in the family Clavariaceae.

Taxonomic characters

Basidiomata are small to medium-sized, mostly branched, with a distinct stalk. Basidiomata are waxy, brittle, or rather tough and variously coloured, from white to orange, ochraceous, cinnamon, purple and lavender (Corner 1950; Petersen 1978). Branches are cylindrical, dichotomous, or polychotomous. Basidiospores are hyaline,

ellipsoid to subglobose, finely verrucose, or echinulate with prominent spines, and cyanophilic in cotton blue. Basidia are clavate, with two to four, straight or slightly curved sterigmata. Basidia are with basal clamp-connection. Hyphae are monomitic, generally narrow, thin- or slightly thick-walled, with clamps-connections, and without secondary septations.

Ecological and economic importance

Ramariopsis species are widely distributed in semi-evergreen to wet evergreen shola forests, and inhabit grasslands, occur in scattered dense clumps on soil, and rarely on rotten wood (Mohanan 2011). The species *R. kunzei* is reported as edible (Wu *et al.* 2019b).

Distribution

The genus Ramariopsis is cosmopolitan in distribution (Corner 1950, 1970; Petersen 1988). ASIA: India (Thind 1961), Kerala (Mohanan 2011); Thailand (Maneevun & Sanoamuang 2010). EUROPE *(*Domański 1984; Jülich 1984, 1985; Petersen 1999; Krieglsteiner 2000), Finland (Shiryev 2008b), Iberian Peninsula (Olariaga & Salcedo 2012); Poland (Błonski 1890; Wojewoda 1974, 2003; Guminska 1976, 1981; Kujawa & Gierczyk 2013; Nowicki & Gierczyk 2013; Halama *et al.* 2017); Eostonia (Shiryev 2009b). NORTH AMERICA: Canada (McAfee & Grund 1982). SOUTH AMERICA: Brazil (Furtado *et al.* 2016; Meiras-Ottoni 2017).

Pterulaceae Corner

The family Pterulaceae comprises of 130 species distributed among seven genera (www.indexfungorum.org, 01 September 2022). They include coralloid and resupinate species. Basidiomata is typically thin, erect, deflexed or decumbent, or resupinate (Corner 1970). Members of the family are characterized by dimitic hyphae (generative and skeletal hyphae), with or without clamp-connections, cystidia may or may not be present, spores are hyaline, smooth, and inamyloid. The Pterulaceae were formally proposed by Corner (1970) to place the genera *Actiniceps* MacMill., *Allantula* Corner, *Deflexula* Corner, *Dimorphocystis* Corner, *Parapterulicium* Corner, *Pterula* Fr., and *Pterulicium* Corner. Leal-Dutra *et al.* (2020) in his molecular

phylogenetic studies removed the genera *Actiniceps* and *Parapterulicium* from Petrulaceaea and added some resupinate genera. *Deflexula* was synonymized with *Pterulicium* (Leal-Dutra *et al.* 2020). Currently, the family Pterulaceae is comprised of seven genera: *Allantula* Corner, *Coronicium* J. Erikss. & Ryvarden, *Merulicium* J. Erikss. & Ryvarden, *Myrmecopterula* Leal-Dutra, Dentinger G.W. Griff., *Phaeopterula* Henn., *Pterula* Fr., and *Pterulicium* Corner (Leal-Dutra *et al.* 2020).

Genus *Pterula* Fries

The genus *Pterula* was erected by Elias Magnus Fries (1821, 1825, 1830), and the typification of this genus was addressed by Lloyd (1919), with *Pterula subulata* Fr. as the type species. Presently, the genus consists of 78 species (www.indexfungorum.org, accessed on 01 December 2022), distributed mainly in the tropics and subtropics, with occurrences reported on all continents except Antarctica (Corner 1970; Leal-Dutra *et al*. 2020). The basidiomata of the genus *Pterula* are highly branched, the hymenium is waxy and generally absent at the stalk, the clavate basidia have smooth spores, cystidia are present, or if absent, caulocystidia are frequently present, dimitic skeltal hyphae are occasionally branched, and the generative hyphae are thin-walled, and mostly with clamp-connections (Corner 1950; Senthilarasu 2013a). Unlike other clavarioid species, *Pterula* generally occurs on humus-covered wood and plant remains (Corner 1950)

At first, *Pterula* was indicated as a *nomen nudum* of "*Clavaria penicillata"* by Fries (1821) without any generic description, and later published as a valid genus (Fries 1825) by grouping all the tropical clavarias with filiform branches (Corner 1952b). In 1832, Fries treated *Pterula* as a subgenus of *Anthina* (Corner 1952a; Perez-Moreno & Villarreal 1989). Throughout the studies, Fries (1821, 1825, 1830, 1832) added numerous exotic or tropical species to the genus. Lloyd (1919) elaborately discussed the taxonomy of the genus *Pterula* (Leal-Dutrra *et al.* 2020). During the late 19th and early 20th centuries, many taxonomic novelties were described in this genus (Corner 1950, 1970). The clavarioid taxa with dimitic hyphae, other than *Petrula* were also included in the Clavariaceae family (Corner 1950; Leal-Dutrra *et al.* 2020). Later, Donk (1964) placed this pteruloid series in the Pteruloideae, a subfamily of the

Clavariaceae. Corner (1970) formally proposed the family Pterulaceae, including the genus *Pterula* along with the other five genera (Leal-Dutrra *et al.* 2020). Petersen (1970) pointed out that the genus *Pterula* is an example of a genus representing separate lines of evolution within Homobasidiomycetes.

Molecular phylogenetic analyses resulted in major changes in the taxonomy of Pterulaceae. Leal-Dutrra *et al.* (2020) did a phylogenetic study on the family Pterulaceae of Corner (1970) and introduced a new ant-associated genus, *Myrmecopterula.* Leal-Dutrra *et al.* (2020) pointed out that "the previously used morphological characters to separate the genus *Pterula* from *Deflexula* (orientation of basidiome growth) are now phylogenetically unreliable." In his study, he retained the clade *Pterula,* to include the true *Pterula* species.

Taxonomic characters

Basidiomata are densely branched or sometimes simple, the stem is generally distinct, short, and slender, the branches are slender or filiform, the hymenium is waxy and generally absent from the stem, the flesh is tough and often fouscus brown. Basidiospores are smooth, ellipsoid to subglobose, basidia are small, clavate, and two- to four-spored. Hyphae are dimitic, skeletal hyphae thick-walled, pale brownish or yellowish walls, dicophyses in some, generative hyphae thin-walled, uninflated, mostly with clamp-connection, cystidia present or absent, gloeocystidia absent, caulocystidia often present. Basidiomata are found on humus, wood, and in dead and decayed leaf litter (Corner 1950; Thind 1961; Pine *et al.* 1999; Leal-Dutrra *et al.* 2020).

Ecological and economic importance

The genus *Pterula* are saprotrophs, with wood decaying property. Many species inhabit soil, few are reported to be associated with living plants, like *Pterula* cf. *tenuissima* (M.A. Curtis) Corner, endophytic in leaves of *Magnolia grandiflora* (Leal-Dutrra *et al.* 2020). Fungicides pterulinic acid (31) and pterulone (32) have been isolated from mycelial cultures of *Pterula* species (Spiteller 2015). Six new linear peptides, pterulamides I-VI (1-6), were isolated from the fruiting bodies of a

Malaysian *Pterula* species (Lang *et al.* 2006). Hydroxystrobilurin A, a new antifungal E-β-methoxyacrylate, noroudemansin A, strobilurin A and oudemansin A were detected in the culture broth of *Pterula* species (Engler *et al.* 1995; 1999).

Distribution

Pterula is a sub-tropical to tropical genus. AFRICA: New Guinea, Congo (Corner 1950); Cameroon (Roberts 1999). ASIA: Malaysia (Corner 1950; Chen *et al*. 2006; Lang *et al.* 2006); China, Philippine (Corner 1950); India (Corner *et al.* 1957; Thind 1961); Mussoorie hills (Corner *et al.* 1957); Maharashtra (Senthilarasu 2013a). AUSTRALIA: New Zealand (Petersen 1988); Solomon Island (Corner 1967); Tasmania (Corner 1950). EUROPE (Corner 1950); Russia (Sidorova & Velikanov 1998; Volobuev 2020). NORTH AMERICA: France (Corner 1950); England, Holland (Corner 1950); Germany (Engler *et al*. 1995; 1999); Mexico (Pérez-Moreno & Villarreal 1989); Montana grassland (Cripps & Caesar 1998); Trinidad (McLaughlin & McLaughlin 1980); U.S.A. (Corner 1952a). SOUTH AMERICA: Brazil (Corner 1950; Leal-Dutra *et al.* 2020); Ecuador (Corner 1950).

Genus *Pterulicium* Corner

The genus *Pterulicium* was proposed by Corner (1950), in his "Monograph of *Clavaria* and allied genera", with *P. xylogenum* (Berk. & Broome) Corner as the type species. Currently, the genus is comprised of 43 species (www.indexfungorum.org, 10 September 2022), distributed mainly in the tropics (Corner 1950). They have resupinate corticium-like patches, freely or sparingly branched basidiomata, a dimitic hyphal system, generative hyphae with clamp-connections, and no cystidia (Corner 1950; Leal-Dutrra *et al*. 2020). In the recent molecular phylogenetic study by Leal-Dutrra *et al*. (2020), the genus *Deflexula* Corner in the family Pterulaceae is synonymized with *Pterulicium*. Corner (1950) proposed the genera *Pterulicium* and *Deflexula* to accommodate dimitic and coralloid (non-bushy) species. He coined the name "*Pterulicium"* based on the combination of the names *Pterula* and *Corticium* Pers. (Leal-Dutrra *et al*. 2020). Whereas, *Deflexula* was named after positively geotropic basidiomes (Corner 1950). Only two corticioid species were reported in the genus *Pterulicium*. They are *P. xylogenum* (Corner 1950) and *P. echo* (D.J.

McLaughlin & E.G. McLaughlin) Leal-Dutrra, Dentinger & G.W. Griff (McLaughlin & McLaughlin 1980). Phylogenetic studies by Munkacsi *et al.* (2004) added sequences from ten species of *Deflexula* and *Pterula* and suggested that "the *Deflexula–Pterula* clade is the sister group of a clade of *Apterostigma* ant symbionts" (Hibbett 2007). According to the phylogenetic studies by Leal-Dutrra *et al*. (2020), the type species of *Deflexula* and *Pterulicium* are nested within the clade *Pterulicium* along with certain *Pterula* species, making both genera polyphyletic. Hence, Leal-Dutrra *et al*. (2020), synonymized *Deflexula* and *Pterulicium*.

Taxonomic characters

Basidiomata are branched, arising from corticium-like or resupinate patches, some are decurved or inverted, branches are polychotomous to dichotomous, or adventitious. Hymenium is waxy, amphigenous, and sterile at the base, and basidiospores are smooth and hyaline. Hyphae are dimitic, with skeletal hyphae and thick-walled generative hyphae with clamp-connections, cystidia are absent (Corner 1950).

Ecological and economic importance

All *Pterulicium* species are wood inhabiting (Corner 1950, 1970). Some *Pterulicium* species are disease causing agents. Culm rot disease of bamboo is caused by *Pterulicium xylogenum* (Leal-Dutrra *et al*. 2020), and sugarcane (Corner 1952a). Certain species of *Pterulicium* are cultivated by ants in the *Apterostigma pilosum* group (Munkasci *et al*. 2004).

Distribution

The genus *Pterulicium* is mainly distributed in the tropics. AFRICA: Uganda (Corner 1950). ASIA: India (Thind & Rattan 1967; Harsh *et al.* 2005; Sandeep 2010); Sri lanka, Malaysia, Philippine (Corner 1950). NORTH AMERICA: Guadeloupe (Corner 1950); USA (Corner 1950). SOUTH AMERICA: Brazil (Corner 1952a); Ecuador (Corner 1950).

Typhulaceae Jülich

The Typhulaceae is a scantily known family of tiny clavarioid Homobasidiomycetes, comprised of 109 species, distributed among three genera (www.indexfungorum.org, accessed on 18 September 2022): *Macrotyphula* R. H. Petersen, *Typhula* (Pers.) Fr., and *Tygervalleyomyces* Crous. (with cupulate conidiomata, Crous (2017)). They are characterized by their epiphytic habitat on wood, stems or leaves, small basidiomata, distinct stipe with fertile head, simple hymenium, smooth, hyaline, ellipsoid spores, monomitic hyphae generally with clamp-connections, and with agglutination of the hyphae on sclerotium (Olariaga *et al*. 2020). Typhuloid fungi represent one of the most overlooked and poorly known groups of Homobasidiomycetes (Olariaga *et al.* 2020). Corner (1950) considered three genera as typhuloid, they are *Typhula*, *Pistillaria* Fr. and *Pistillina* Quel. Berthier (1976), studied typhuloid fungi in a broad sense in his monograph "*Typhula* and allied genera" and included *Ceratellopsis* Konrad & Maubl., *Macrotyphula* R.H. Petersen, *Pterula* and *Typhula* as a natural group (Olariaga *et al.* 2020). Jülich (1982) also accommodated the genus *Ceratellopsis* in the family Typhulaceae. Kirk *et al*. (2008) included the genus *Sclerotium* (currently an artificial genus) in the Typhulaceae (Xu *et al*. 2010). *Tygervalleyomyces* Crous is a new monotypic genus treated in Typhulaceae based on the analysis of the 28S region (Crous *et al*. 2017).

Due to the weakly supported phylogenies with very limited taxon sampling, the family level classification of this group of fungi is uncertain. Using multilocus phylogenetic studies on the clades of Agaricales, Matheny (2006) recovered Typhulaceae in the hygrophoroid clade (Agaricales). Currently, only three genera are treated in the family Typhulaceae. They are *Macrotyphula*, *Typhula* and, the monotypic genus *Tygervalleyomyces*. Other genera (*Pistillaria*, and *Pistillina*) were synonimized with *Typhula* (www.indexfungorum.org).

Genus *Macrotyphula* R. H. Petersen

The genus *Macrotyphula* was proposed by Petersen (1972) to accommodate *M. fistulosa*, which was previously placed in the genus *Clavariadelphus* (as *C. fistulous*). They are saprotrophic clavarioid species,

most of which are devoid of sclerotium. The genus currently comprises of six species (www.indexfungorum.org, accessed on 08 December 2022), mostly distributed in temperate regions, with fewer reports from the tropics. Earlier, typhuloid fungi were treated as a natural group by including the genera *Ceratellopsis, Macrotyphula, Pterula,* and *Typhula.* The family-level classification of this group was uncertain (Berthier 1976; Olariaga *et al.* 2020). Corner (1970) and Hawksworth *et al.* (1995) placed *Macrotyphula* and *Typhula* in Clavariadelphaceae. Later, Kirk *et al.* (2008) transferred both genera to Typhulaceae (Knudsen & Vesterholt 2012; Olariaga *et al.* 2020). *Macrotyphula* differs from *Typhula* in having large, yellowish-brown, filiform basidiomata (30–300 mm) without sclerotia (Berthier 1976). Previous studies by Pine *et al.* (1999) and Hibbett *et al.* (2007) showed that *T. phacorrhiza* formed a monophyletic group with *Macrotyphula.* Hence, Olariaga & Salcedo (2012) supported the view of synonymizing *Macrotyphula* with *Typhula. T. phacorrhiza* with long filiform basidiomata, is not a typical *Typhula* species (Remsberg 1940; Corner 1950; Berthier 1976). Recent phylogenetic origins and family-level classification of typhuloid fungi by Olariaga *et al.* (2020) introduced a new family Phyllotopsidaceae, which included the genera *Macrotyphula, Phyllotopsis,* and *Pleurocybella*. However, according to the Index Fungorum (accessed on 01 December 2022), *Macrotyphula* is still placed in the family Typhulaceae.

Taxonomic characters

Basidiomata simple, filiform, and large. Basidiospores smooth, subglobose to ellipsoid, basidia tetra-sterigmate. Hyphae monomitic, inflating, with or without clamp-connections. Cystidia often present. Sclerotium absent. (Berthier 1976).

Ecological importance

Macrotyphula is a saprotrophic genus found on decaying leaves and twigs.

Distribution

The genus is distributed mostly in temperate regions, with sparse reports from tropics. ASIA: Corner (1950), India (Khurana 1980). AUSTRALIA: New Zealand

(Petersen 1988). EUROPE: Corner (1950). NORTH AMERICA: Mexico (Perez moreno & Villarreal 1991; Corner 1950).

Genus *Typhula* (Persoon) Fries

The genus *Typhula,* characterized by its small basidiomata, was first introduced by Persoon (1801) as a section of *Clavaria*. But the name was taken to a generic level by Fries (1818), with *Typhula phacorrhiza* (Reichardt) Fr. as the type species (www.indexfungorum.org). The genus *Typhula* comprises of 108 species (www.indexfungorum.org, accessed on 01, December 2022), described mostly from the north temperate zone, with less reports from the tropics or southern hemisphere. The generic name *Typhula* was derived from the Latin word "*Typha"*, which means "reed-mace," in accordance with the basidiomata of this genus (Massee 2015; Kaygusuz & Çolak 2017). The genus was distinguished by filiform to club-shaped basidiomata with a corticioid stipe and a filiform fertile head, often arising from the sclerotium, normally white, rarely pinkish to red, spores are smooth, ellipsoid, hyphae are monomitic and inflated, with caulinar hairs or gellifications in some, with or without clamp-connections. Sclerotia are small, globose or more or less flattened, generally yellow, brown, or black, with agglutinated hyphae, often with crystals (Corner 1950; Thind 1961; Olariaga & Salcedo 2009).

Fries (1821), in his "*Systema Mycologicum,"* retained the genus *Typhula* under the sub-order 'Clavati' of the Hymenomycetes. He then divided the genus into two groups based on the presence of sclerotia. The basidiomycetous identity of *Typhula* was not recognized until after the middle of the nineteenth century (Remsberg 1940). It was Fuckel (1869) who placed the genus *Typhula* under the class Basidiomycetes. Fries (1874) listed 23 species of *Typhula* under two subdivisions. They are *Phacorrhiza* with sclerotia and *Leptorrhiza* without sclerotia (Remsberg 1940). The genus was revised by Corner (1950), who characterized *Typhula* as having basidiomata arising from sclerotia. The genera *Pistillaria* and *Pistillina* are closely related to *Typhula* in basidiomatal morphology but differs by the absence of sclerotia (Olariaga *et al.* 2020). The major revision in the genus *Typhula* was made by Berthier (1976), who placed *Pistillaria* and *Pistillina* as synonyms of *Typhula*. Another genus

which closely resembles *Typhula* is the genus *Macrotyphula* described by Petersen (1972). It differes from the former by its large, yellow-brown basidiomata, absence of sclerotia, and non-amyloid spores (Berthier 1976; Olariaga 2021). Genera such as *Cnazonaria, Dacryopsella, Gliocoryne, Phacorhiza, Pistillaria, Pistillina, Scleromitra,* and *Sphaerula* were segregated from *Typhula*, with diverse basidiome morphologies, sclerotial anatomy and anamorph states (Berthier 1976). By studying extensive materials and type specimens, Berthier (1976) merged all this under the genus *Typhula*.

Phylogenetic studies by Hibbett *et al.* (1997), Pine *et al.* (1999), Binder & Hibbett (2002), and Larsson *et al.* (2004) agree that *Typhula* and *Macrotyphula* form a lineage of clavarioid fungi nested in the euagarics/Agaricales clade (Olariaga & Salcedo 2009). Matheny *et al.* (2006) suggested that *Typhula* and *Pterula* are members of the same lineage, although *Pterula* has been treated as an independent lineage (Dentinger & McLaughlin 2006; Olariaga & Salcedo 2009). The genus *Typhula* was previously placed in the family Clavariadelphaceae (Corner 1970; Hawksworth *et al.* 1995). But recent classifications (Knudsen & Vesterholt 2012) place the genus in the family Typhulaceae (Kirk *et al.* 2008; Olariaga *et al*. 2020).

Taxonomic characters

Basidiomata simple, rarely branched in a few species, very small to elongate, slender, with a filiform sterile stalk, subglobose, clavate, cylindric, or elongate filiform fertile head, mostly arising from a sclerotium, spores are white, smooth, ellipsoid with thin-walls, basidia mostly tetra-sterigmate, hyphae monomitic, inflated, with or without clamp-connections, subhymenium not secondarily septate, occasional uninflated hyphae with resinous oleaginous contents, caulocystidia generally present. Sclerotium small, globose, more or less flattened, generally yellow, brown, or black, with agglutinated hyphae, often encrusted with crystals on the surface (Thind 1961, Corner 1950; Berthier 1976).

Ecological and economic importance

The genus *Typhula* mostly occurs as saprotrophs on decomposing stems, fallen leaves, twigs, and woody detritus. "Snow moulds" or "*Typhula* blight" disease in crops and turfgrass are caused by *T. incarnata* and *T. ishikariensis.* (Ekstrand 1955; Knudsen 1997a; Matsumoto *et al.* 2001; Hoshino *et al*. 2008, 2009; Ikeda *et al*. 2015; Kaygusuz & Çolak 2017). Certain *Typhula* species, such as *T. variabilis* Riess and *T. japonica* Terui, were reported to cause decay of carrot roots under snow, with rotting of the root crown (Ikeda *et al*. 2016).

Distribution

The genus *Typhula* distributed mainly in north temperate regions (Corner 1950). ANTARTICA (Yajima *et al.* 2017). ASIA: India (Thind 1961; Khurana 1980); Japan (Matsumoto & Tajimi 1993; Corner 1950; Ikeda *et al.* 2015, 2016, 2017; Hoshino *et al*. 2009; Kasuya *et al.* 2016); Turkey (Kaygusuz & Çolak 2017; Işik 2020); Uzbekistan (Gafforov & Hoshino 2015). EUROPE: (Corner 1950); Iberian Peninsula (Olariaga & Salcedo 2009); Russia, Oryol (Volobuev 2012; Kowalski & Bilański 2021). NORTH AMERICA: Brazil (Martin 1956); Canada, Finland, Germany, Spain, Italy (Corner 1950); France, Spain, Sweden (Corner 1950; Olariaga *et al* 2016); Faroe Island (Hoshino *et al.* 2004); England, Norfolk (Corner 1950; Edwards *et al.* 2014); Iceland (Hoshino *et al.* 2004); Pacific Northwest (Bruehl & BM 1975); U.S.A., Wisconsin, Utah, Michigan, Minnesota (Chang *et al.* 2006); Norway (Matsumoto & Tronsmo 1995); Poland (Wojewoda 2000).

2.6. **ORDER CANTHARELLALES** Gäumann

The order Cantharellales was established by Gäumann in 1926. Currently, the order includes five families, 35 genera, and about 629 species (www.indexfungorum.org, 01 December 2022). Cantharellales members have a cosmopolitan distribution and include species with varying basidiocarp morphology. Resupinate (*Tulasnella* J. Schrot., *Botryobasidium* Donk), hydnoid (*Hydnum* L.), pileate-stipitate (*Craterellus* Pers., *Cantharellus* Adans. ex Fr.), and clavarioid basidiomata (*Clavulina* J. Schrot., *Multiclavula* R.H. Petersen, *Aphelaria* Corner) are produced. Species with cyphelloid and bulbil-forming asexual propagules (*Rhizoctonia* D.C., *Ceratorhiza* R.T. Moore) are also encountered (Olariaga 2021). Species within this order are mostly ectomycorrhizal (*Cantharellus, Clavulina, Craterellus, Hydnum,* and *Sistotrema*) and saprotrophic (*Botryobasidium, Tulasnella,* and *Ceratobasidium* D.P. Rogers). Species forming associations with orchids and liverworts (*Tulasnella)* (Preußing *et al*. 2010), algae (*Burgella* Diederich & Lawrey and *Burgoa* Goid.), and higher plants as endophytes have been reported (Suarez *et al.* 2006; Diederich & Lawrey 2007; Dearnaley *et al.* 2016; Olariaga 2021). The basidiomata of species belonging to this order are characterized by smooth to wrinkled hymenophores. Basidia are more than four sterigmate (exceptionally two in the genus *Clavulina*), epibasidia are suburniform or urniform stichic, clavate or cylindrical, or swollen septate. Repetitive spore formation is observed in Ceratobasidiaceae and Tulasnellaceae (Corner 1950; Monocalvo *et al.* 2006; Olariaga 2021). Septal pore ultrastructure has been used to infer relationships within the Cantharellales. Botryobasidiaceae and Tulasnellaceae possess imperforate parenthesomes, *Cantharellus* and *Sistotrema*, and a few species of *Rhizoctonia* have perforated parenthesomes (Van Driel *et al.* 2009; Olariaga 2021).

The order Cantharellales initially included fungi that produce cantharelloid basidiomata. The concept has later been modified to include species with varying basidial morphology. Persoon (1825) included the genus *Craterellus* having basidiomata with a hollow stipe. Donk (1933) placed the genus *Hydnum* with basidiomata having a toothed or spiny hymenophore in the order Cantharellaes due to

the presence of stichic basidia. Besides these, some other aphyllophoroid genera with diverse basidiomatal morphology, such as *Auriscalpium*, *Sarcodon*, *Clavaria*, *Clavariadelphus*, *Clavulina*, *Clavulinopsis*, *Multiclavula*, *Typhula*, *Pterula*, *Ramaria*, *Sparassis*, and the poroid *Albatrellus*, were also placed in Cantharellales (Donk 1964; Monocalvo *et al*. 2006). Gaumann (1926) originally proposed the order Cantharellales to accommodate those species having stichic basidia. Based on this, he recognized three families (Cantharellaceae, Clavulinaceae, and Exobasidiaceae) within this order. Presently, Exobasidiaceae is placed in a separate order, Exobasidiales (www.indexfungorum.org). Hawksworth *et al.* (1995) modified the order Cantharellales to include the families Aphelariaceae, Clavariaceae, Clavariadelphaceae,Clavulinaceae, Craterellaceae, Hydnaceae, Physalacriaceae, P terulaceae, Scutigeraceae, Sparassidaceae, and Typhulaceae.

Molecular phylogenetic analyses using DNA sequences has redefined the order Cantharellales. Hibbett *et al.* (1997) was the first to use DNA sequencing and phylogenetic analyses to infer the evolutionary relationships of homobasidiomycetes (Monocalvo *et al.* 2006). With the help of nuclear (nSSU) and mitochondrial (mtSSU) small ribosomal subunit RNA genes, they hypothesized a common origin for *Cantharellus, Hydnum, Clavulina, Multiclavula,* and members of the corticioid genus *Botryobasidium*. Their study also proposed the exclusion of genera like *Gomphus* and *Clavaria* from the Cantharellales. Subsequent phylogenetic studies (Pine *et al.* 1999; Hibbett *et al.* 2000; Hibbett & Donoghue 2001; Hibbett & Binder 2002; Binder & Hibbett 2002; Larsson *et al.* 2004; Binder *et al.* 2005) assigned the resupinate taxa *Sistotrema, Membranomyces,* and the Ceratobasidiaceae to the cantherelloid clade (Monocalvo *et al.* 2006). Hibbett & Thorn (2001) included the heterobasidiomycete genus *Tulasnella* in the cantherelloid clade based on the mtLSU phylogenetic analysis. In phylogenetic studies of the Cantharellales (Hibbett & Thorn 2001; Matheny *et al.* 2006; Moncalvo *et al*. 2006; González *et al*. 2016; Olariaga 2021), four monophyletic families were consistently recovered. They are Hydnaceae, Cejpomycetaceae, Tulasnellaceae, and Botryobasidiaceae. Latest phylogenetic investigations in the order Cantharellales resulted in the synonymization of the families Cantharellaceae, Clavulinaceae, and Sistotremataceae with Hydnaceae

(Olariaga *et al.* 2021) and the synonymization of the family Cejpomycetaceae with Ceratobasidiaceae (Oberwinkler *et al.* 2013).

Currently, the order Cantharellales consists of five families (Aphelariaceae, Botryobasidiaceae, Ceratobasidiaceae, Hydnaceae, and Tulasnellaceae) and 35 genera (www.indexfungorum.org, accessed on 01 December 2022).

Aphelariaceae Corner

The family Aphelariaceae was proposed by Corner (1970). The family consists of three genera and 21 species (www.indexfungorum.org, accessed on 06 November 2022). The family was erected to accommodate tropical and subtropical clavarioid fungi with bifid to multifid branching, white inamyloid spores, and monomitic uninflated hyphae. According to Corner (1970), Aphelariaceae is closely related to Clavariaceae, but differs by the absence of uninflated hyphae in the former. Members of the Aphelariaceae are terrestrial and typically found in woodlands. According to Index Fungorum (www.indexfungorum.org, accessed on 06 January 2023), the family currently consists of three genera: *Aphelaria*, *Phaeoaphelaria* and *Tumidapexus.*

Genus *Aphelaria* Corner

The genus *Aphelaria* was proposed by Corner (1950) with *Aphelaria dendroides* Corner as the type species, to include clavarioid fungi with flattened branching (Reid 1955; Corner 1966b). The genus *Aphelaria* is characterized by basidiomata with flattened multifid or bifid branching, slightly thick-walled, and uninflated hyphae without clamp-connections (Thind 1961; Corner 1966b). Corner (1953) divided the genus into two subgenera: *Aphelaria* and *Tremellodendropsis* (Reid 1955). Species with normal clavarioid basidia and without clamp-connections were placed in the subgenus *Aphelaria*, whereas, those with transversely septate basidia and clamp-connections were considered in the subg. *Tremellodendropsis* (Reid 1955; Thind 1961; Corner 1966b). Later, it was Crawford (1954) who separated *Tremellodendropsis* from *Aphelaria*, and raised the former as a separate genus (Corner 1966b). Currently, *Aphelaria* is comprised of 19 species (www.indexfungorum.org, accessed on 06 November 2022).

Taxonomic characters

Basidiomata have flattened branching with multifid or bifid branch tips and may be white, pale grey, yellowish, brownish, or pale flesh-coloured. Basidiospores are smooth and hyaline, basidia are clavate and aseptate, hyphae are slightly thick-walled and typically without clamp-connections (Thind 1961; Corner 1966b).

Distribution

The genus *Aphelaria* has tropical and subtropical distribution (Corner 1950). AFRICA (Corner 1950). ASIA: India (Thind & Sukhdev 1956); Malaysia, Philippines (Corner 1950). AUSTRALIA: New Zealand. NORTH AMERICA: Cuba (Corner 1950). SOUTH AMERICA: Brazil (Corner 1950).

Hydnaceae Chevallier

The family Hydnaceae was proposed by Chevallier (1826) to include all fungi with a downward facing spiny and tooth-like hymenium. At present, the family is characterized by varying basidiocarp morphology (hydnoid, cyphelloid to clavarioid, and cantharelloid), clavate to suburniform or urniform stichic basidia, non-repetitive spores, and the presence of clamp-connections on the tramal hyphae (Donk 1964; Olariaga *et al.* 2021). Ectomycorrhizal Cantharellales exclusively belong to the family Hydnaceae (Nilsson *et al.* 2006; Di Marino *et al.* 2008; Olariaga *et al*. 2021). It was reported that basidiomata of fleshy Hydnaceae last longer (Largent & Sime 1995; Norvell 1995), and some are resistant to insect predation (Pilz *et al.* 2003; Masota *et al.* 2017).

Donk (1933), referred the family Hydnaceae as a tribe "Hydneae" in Cantharelloideae, and restricted it to include the species that produce stichic basidia. Considering this characteristic feature, the species were further moved closer to *Canterellus* than other hydnoid genera. Later, this concept was widely accepted and the family Hydnaceae was placed in the order Cantharellales (Donk 1964; Hawksworth *et al.* 1995). Molecular phylogenetic studies (Pine *et al.* 1999; Larsson 2004; Monocalvo 2006; Larsson 2007; Olariaga 2021) revised the generic composition within the family Hydnaceae. Currently, the family consists of 19 genera

and approximately 400 species (www.indexfungorum.org, accessed on 01 November 2022). Members are with a cosmopolitan distribution.

Genus *Clavulina* J. Schröeter

Clavulina is the only genus in the family Hydnaceae with coralloid basidiomata. At present, the genus consists of 105 species (www.indexfungorum.org, accessed on 20 November 2022). Distribution is mainly tropical (Corner 1950; Petersen 1983; Tedersoo *et al.* 2003; Thaker & Henkal 2004; Felipe 2012; Henkel *et al*. 2012). Most species of *Clavulina* are ectomycorrhizal, and a few are lignicolous (Corner 1950; Uehling *et al.* 2012). The diagnostic characters of the genus include coralloid basidiomata with amphigenous hymenia, bi-sterigmate basidia with stichic nuclear division, curved sterigmata, and smooth, hyaline, guttulate basidiospores (Corner 1950, 1970; Petersen 1988). Transverse basidial septa formed after basidiospore release is also a diagnostic character of the genus *Clavulina* (Corner 1950, 1970).

The genus *Clavulina* was originally proposed by Schröeter (1889) with *Clavulina cristata* J. Schröt. as the type species, based on the presence of bi-sterigmate basidia and subglobose to globose basidiospores. However, the discovery of the stichic position of the first meiotic spindles made the evolutionary origin of the genus ambiguous (Donk 1964). The placement of stichic and chiastic spindle formation as a primary taxonomic character had caused much confusion over the years (Petersen 1967a). Corner (1950, 1957) gave importance to the hyphal construction of basidiomata as a taxonomic character. According to his hypothesis, the stichic genera *Clavulina* and *Cantharellus* were allied to the chiastic genera *Clavulinopsis* and *Clavariadelphus*. Corner (1950, 1970) also noticed a transverse basidial septa formed after basidiospore release as a diagnostic character for the genus *Clavulina*. He classified the genus into four subgenera based on certain characters such as hyphal wall colour, presence or absence of clamp-connections, and presence or absence of cystidia. The four sub groups of Corner (1950, 1970) are: *Fusco-Clavulina* with brown hyphal walls; *Eu-Clavulina* without clamp-connections; *Eu-Clavulina* with clamp-connections and cystidia; *Eu- Clavulina* without clamp-connections and

cystidia. Donk (1964) recognized a distinct family, the Clavulinaceae, within the Cantharelloideae to accommodate the genus *Clavulina* with stichic basidia (Petersen 1967a). Corner (1970) agreed to Donk's concept of Clavulinaceae. However, Petersen (1988) did not include transverse septation in basidia as a character in his species descriptions. He noted that such postpartal septa may be localized on a basidiome or absent entirely (Thaker & Henkel 2004).

Though bi-sterigmate basidia is a diagnostic character of the genus *Clavulina*, species with more than two sterigmata also exist (Corner 1950; Petersen 1988; Thaker & Henkel 2004; Olariaga *et al.* 2009). *C. amazonensis* Corner consists of two to four sterigmata per basidium and was placed in *Clavulina* due to the presence of curved sterigmata, though many other features are lacking (Corner 1970; Petersen 1988b; Thaker & Henkel 2004). Thaker & Henkel (2004) pointed out that coralloid basidiomata and bi-sterigmate basidia are not fully diagnostic of the genus *Clavulina.* A Neotropical species (*C. craterelloides* Thacker & T. W. Henkel) forming infundibuliform basidiomata rather than coralloid forms, and basidium bearing four to six spores have been recently included in the genus *Clavulina* based on nLSU sequence data (Thacker & Henkel 2004; Henkel *et al* 2005; Monocalvo *et al*. 2006). It was Hibbett *et al*. (1997) who first indicated the placement of the genus *Clavulina* in the cantharelloid clade. Later studies also supported the monophyly of *Clavulina* within the Cantharellales (Thacker & Henkel 2004; Moncalvo *et al.* 2006; Uehling *et al*. 2012). Hibbett *et al.* (2014) supported the division of the order Cantharellales into four families (Ceratobasidiaceae, Tulasnellaceae, Botryobasidiaceae, and Hydnaceae), and excluded the family Clavulinaceae. Hibbett *et al.* (2014) pointed out that the corticioid genus *Membranomyces* shares some micromorphological characters, ectomycorrhizal habits, and phylogenetic relationships (Larsson *et al*. 2004; Binder *et al*. 2005; Monocalvo *et al*. 2006) with the genus *Clavulina*. Thus, together, they form a separate lineage within the family Hydnaceae. Hibbett *et al.* (2014) synonymized the family Clavulinaceae with Hydnaceae.

Taxonomic characters

Basidiomata are simple to branched, waxy or rather brittle, rarely infundibuliform (Thacker & Henkel 2004; Henkel *et al*. 2005; Monocalvo *et al.* 2006), branching generally flattened or slightly dorsiventral, hymenium sterile in some species, tips cristate, white to variously coloured. Basidiospore are subglobose or broadly ellipsoid, smooth, and contains large oil guttules. Basidia are subcylindric, usually secondary septate after spore discharge, mostly stichic, generally with two curved and short, rarely straight sterigmata. Hyphae monomitic, slightly thick-walled, more or less inflated, usually with clamp-connections, and secondarily septate in species that lack clamp-connections. Cystidia may be present or absent (Corner 1950; Thind 1961).

Ecological and economic importance

The genus *Clavulina* belongs to an ectomycorrhizal group of fungi in the family Hydnaceae (Tedersoo *et al.* 2003; Bue'e *et al.* 2005; Moyersoen 2006; Olariaga 2009; Uehling *et al.* 2012). They are saprotrophic and lignicolous (Corner 1950). Many *Clavulina* species (*C. cristata* (Holmsk.) J. Schrot., *C. rugosa* (Bull.) J. Schrot.) are edible (Philip *et al*. 1991; Agrahar & Subbulakshmi 2005; Ian Burrows 2005; Renu Rana 2016). *Clavulina cinerea* (Bull) J. Schröt., produces lignocellulolytic enzymes for the decomposition of plant material (Osono 2007). *Clavulina* species have antiproliferative, immunostimulatory, and antiinflammatory properties (Deo *et al.* 2019). Njue *et al.* (2017) reported the presence of cytotoxic triterpenoids in *C. cinerea*. Dried extracts of *C. cinerea* show insecticidal properties (Mier *et al.* 1996). Metabolites isolated from *C. cinerea* are used as antioxidants, with ascorbic acid as the main ingredient (Agrahar & Subbulakshmi 2005).

Distribution

The genus *Clavulina* has a world-wide distribution. AFRICA (Rasalanavho *et al*. 2019); Cameroon (Roberts 1999); Madagaskar (Duhem & Buyck 2007). ASIA: Azerbaijan (Mustafabayli *et al.* 2021); China (He *et al*. 2016; Wu *et al*. 2019a; Tan & Zhao 2020); Japan (López & García 2019); Malaysia (Corner 1950; Hamzah &

Mohammad 2021); India (Thind 1961; Verma & Pandro 2018), Kerala (Mohanan 2011); Bangladesh (Marzana *et al.* 2018); Indonesia (Arko *et al.* 2017); Java (Firdaus *et al.* 2016); Korea (Kim *et al*. 2020); Tibet (Wang *et al.* 2015). AUSTRALIA: New Zealand (Corner 1950, 1986; Petersen 1983); Tasmania (Corner 1950). EUROPE (Corner 1950; Olariaga *et al.* 2009); France; Finland (López & García 2019); (Estonia (Shiryaev 2009); Russia (Govorova 1999). NORTH AMERICA: U.S.A; West Indies; Florida; Porto Ricco; Mexico (Oros-Ortega *et al.* 2017; Eduardo *et al*. 2019; Uitzil-Colli & Arana Yepez 2021); Canada (Deo *et al*. 2019). SOUTH AMERICA: Argentina; Guyana (Thacker & Henkal 2004; Henkel *et al.* 2005; Henkal *et al.* 2012a; Uehling *et al.* 2012); Brazil (Corner 1950; Felipe 2012).

2.7. ORDER GOMPHALES Jülich

The order Gomphales was proposed by Jülich (1981), and consists of 651 described species in three families and 18 genera (Kirk *et al.* 2008; Giachini *et al.* 2010). The members have a cosmopolitan distribution, with more reports from the temperate zones of the northern hemisphere (Petersen 1971a; Kirk *et al.* 2008; Avila *et al.* 2017). The gomphoid fungi show great variations in basidiomatal morphologies, from stalked ramarioid or clavarioid to cantharelloid-gomphoid, resupinate, odontoid, or sequestrate (Giachini *et al.* 2010; Avila *et al.* 2020). The order Gomphales also shows heterogeneity in their ecological characteristics, with saprotrophic and symbiotic associations (Hosaka *et al*. 2006; Hibbett *et al.* 2014; Avila *et al*. 2017). Gomphoid fungi are characterized by cyanophilic spores, chiastic basidia, and a positive hymenial reaction to iron salt (Giachini *et al.* 2010; Avila *et al.* 2013a, 2020).

Donk (1961, 1964) proposed the family Gomphaceae in the order Aphyllophorales to include the genera *Kavinia* Pilat and *Ramaricium* J. Erikks. (resupinate), *Lentaria* Corner and *Ramaria* Holmsk. (coralloid), *Beenakia* D.A. Reid *(*hydnoid), *Gloeocantharellus* Singer (agaricoid), *Chloroneuron* Murrill, and *Gomphus* Pers. (pileate). Corner (1970) proposed the family Ramariaceae in the order Aphyllophorales, to include *Delentaria* Corner, *Kavinia, Lentaria,* and *Ramaria*. He excluded the pileate genera since no intermediate species were available to link between the gomphoid and the ramarioid morphologies (Giachini 2010). Petersen (Petersen 1973, 1988) revised the familial classifications of Donk (1961, 1964) and Corner (1970) to include *Beenakia*, *Gomphus, Kavinia*, *Ramaricium*, *Ramariopsis* (Donk) Corner, and *Ramaria*. Julich (1981) proposed the order Gomphales, and Villegas *et al.* (1999) using morphological traits suggested monophyly of the order keeping the families Beenakiaceae, Gomphaceae, Lentariaceae, and Ramariaceae. Hosaka *et al*. (2006), Hibbett *et al.* (2007), Kirk *et al.* (2008), and Giachini *et al.* (2010) placed Gomphales within the subclass Phallomycetidae, of Agaricomycotina.

Pine *et al.* (1999), Humpert *et al.* (2001), and Hosaka *et al.* (2006) considered the genera *Beenakia, Clavariadelphus* Donk, *Gautieria* Vittad., *GloeocantharelIus, Gomphus, Kavinia, Lentaria, Phaeoclavulina* Brinkmann, *Ramaria, Ramaricium*, and

Turbinellus Earle in Gomphales. Giachini (2010) recognized nine genera (*Clavariadelphus, Gautieria, Gloeocantarellus, Gomphus, Kavinia, Lentaria, Phaeoclavulina, Ramaria,* and *Turbinellus*). Humpert *et al.* (2001) proposed that branched coral basidiomata are the ancestral forms of Gomphales. Phylogenetic hypotheses based on molecular data suggest that Gomphales are a sister group to Phallales (Hosaka *et al.* 2006).

At present, the order Gomphales includes 3 families, Clavariadelphaceae, Gomphaceae, and Lentariaceae, and 18 genera (*Araeocoryne* Corner, *Beenakia, Ceratellopsis* Konrad & Maubl., *Clavariadelphus, Delentaria, Destuntzia* Fogel & Trappe, *Gautieria, GloeocantharelIus, Gomphus, Kavinia, Lentaria, Phaeoclavulina, Protogautieria* A.H. Sm., *Pseudogomphus* R. Heim., *Ramaria, Ramaricium, Terenodon* Maas Geest. and *Turbinellus* (www.indexfungorum.org)).

Gomphaceae Donk

The family Gomphaceae was proposed by Donk (1961) in the order Aphyllophorales to incorporate macroscopically heterogenous fungi, which differ in their hymenial structure. He included the resupinate-odontoid genera *Kavinia* and *Ramaricium*, the stalked clavarioid genera *Lentaria* and *Ramaria*, the stalked hydnoid genus *Beenakia*, the stipitate agaricoid genus *Gloeocantharellus*, and the pileate genera *Chloroneuron* Murrill and *Gomphus* in his familial classification. In the Friesian system of classification, these genera were spread over four families, such as Cantharellaceae, Clavariaceae, Corticiaceae, and Hydnaceae, based on the macroscopic features of the basidiomata. Ornamented, ellipsoid, cyanophilic, ochraceous to hyaline spores with rugose walls, and the greenish colour change of hymenium on reaction with iron salt, are characteristic of members of the family (Donk 1961; Villegas *et al.* 1999).

Petersen (1971) and Maas Geesteranus (1971) studied the family and transferred the genera *Gloeocantharellus* and *Psathyrodon* Mass Geest. (now *Beenakia* D.A. Reid) to Gomphaceae (Villegas *et al.* 1999). Genera like *Clavariadelphus*, *Cantharellus*, and *Ramariopsis* showed affinities with Gomphaceae (Corner 1950; Julich 1981; Methven 1990; Petersen 1971, 1988; Welden 1966). The

family was a member of the order Aphyllophorales until Jülich (1981) proposed the order Gomphales. Villegas *et al.* (1999), using molecular characters, proposed the monophyly of Gomphales and modified the family Gomphaceae by limiting the number of genera into two (*Gomphus* and *Gloeocantharellus*). Giachini (2004) revised the generic concepts in the family Gomphaceae and recombined the species of *Gomphus sensu lato* into *Gloeocantharellus, Gomphus sensu stricto*, and the resurrected genera *Phaeoclavulina* and *Turbinellus.*

Currently, the family Gomphaceae consists of 14 genera. They are *Araeocoryne, Ceratellopsis, Delentaria, Destuntzia, Gautieria, GloeocantharelIus, Gomphus, Phaeoclavulina, Protogautieria, Pseudogomphus, Ramaria, Ramaricium*, *Terenodon,* and *Turbinellus* (www.indexfungorum.org, accessed on 10 June 2022).

Genus *Gomphus* Persoon

The genus *Gomphus* was proposed by Persoon (1797) to include cantharelloid-gomphoid species that resemble the basidiomata of *Cantharellus* (Giachini 2004). The genus has been described from many parts of the world, with most reports from the U.S.A. (Segedin 1984). Some species are reported as mycorrhizal (*G. clavatus*) (Agerer *et al.* 1998) and red-listed (*G. clavatus* Pers.) (Dahlberg & Croneborg 2003; Giachini & Castellano 2011). The genus *Gomphus* is characterized by unipileate to merismatoid, deep violet to lavender, brownish to orangish yellow basidiomata, which are fan- to slightly funnel-shaped, wrinkled hymenia, strictly verrucose spores, and a positive hymenial reaction to iron salt (Giachini *et al*. 2012).

The genus *Gomphus* can be segregated from the genera *Clavaria, Geoglossum, Mitrula*, *Merulius,* and *Spathularia* (Giachini *et al.* 2012; Petersen 1971a), based on the truncate, unipileate, meristamoid, or weakly developed, smooth, and laterally plicate-venose pileus (Persoon 1797; Giachini *et al.* 2012). Earlier, the genus *Merulius* did not include resupinate forms, but was composed of stalked basidiomata with wrinkled hymenium. Persoon (1797) described the species *M. clavatus* Pers. as having merismatoid basidiomata with an orangish brown to violet colour and verrucose ornamented spores (Petersen 1797; Giachini *et al.* 2012). Persoon (1797a) first used *Gomphus* as a genus name without assigning any species

and later as a section of the genus *Merulius* (Persoon 1801; Petersen 1797). Fries (1821) placed *Gomphus* as a tribe of *Cantharellus* with a single species, *C. clavatus* (Petersen 1797). *Gomphus* was reassigned as a separate genus by Gray (1821) for a single species, *G. clavatus* (Giachini *et al.* 2012) as the type species.

Donk (1933) proposed the tribe *Ramariae* and included *Gomphus* and *Ramaria* in it. Donk (1961) defined the family Gomphaceae by adding the genera that differ widely in hymenial configuration. Of these genera, *Gomphus* is with pileate hymenium. Later, with the help of molecular tools, Giachini (2004) and Giachini & Castellano (2011) studied the systematics of the order Gomphales and its related genera. Based on the presence or absence of clamp-connections, spore ornamentations, and basidiomal morphology, Giachini (2004, 2011) narrowed down taxa earlier considered as *Gomphus sensu lato* into *Gomphus sensu stricto*, *Turbinellus, Gloeocantharellus,* and *Phaeoclavulina*. Species of *Gomphus sensu stricto* were initially scattered over three different genera: *Cantharellus, Craterellus*, and *Neurophyllum* Pat. (Fries 1821; Fries 1838; Doassans & Patouillard 1886; Giachini *et al.* 2012). The new classification by Giachini (2004) and Giachini & Castellano (2011) pointed out that *Gomphus sensu stricto* is the only genus in the family Gomphaceae with strictly violet, lavender-brown, or milky-coffee coloured hymenia (Giachini *et al.* 2012). Currently, the genus *Gomphus* consists of 16 species (www.indexfungorum.org, accessed on 18 September 2022).

Taxonomic characters

Basidiomata unipileate or merismatoid, with fan-shaped to slightly funnel-shaped pileus, hymenium decurrent with wrinkled hymenial folds, or longitudinally rigid to merulioid or irregularly poroid. Basidiomatal colour varies from bright violet, pale olivaceous, light brown, brown, to vinaceous brown. Basidiospores are strictly verrucose. Hyphal clamp-connections are present. Hymenial cystidia are absent, and pileocystidia may be present or absent (Petersen 1971a; Giachini *et al.* 2012).

Ecological and economic importance

G. clavatus has been reported to form mycorrhizal associations with species of *Abies* and *Picea* (Agerer *et al.* 1998; Giachini *et al.* 2012). *G. clavatus* is medicinal, with antioxidant and anticancerous activities (Makropoulou *et al.* 2012; Ding *et al.* 2015). It is a widely consumed, edible mushroom (Pilz *et al.* 2003; Makropoulou *et al.* 2012), which ranked highest in the multifunctional food index in an investigation in Mexico (Garibay *et al.* 2007; Makropoulou *et al.* 2012).

Distribution

The genus *Gomphus* has been reported from all over the world, mainly from the northern hemisphere. AFRICA: Algeria (Dufour 1889; Maire 1914); Cameroon (Roberts 1999); Morocco (Malençon 1958); The Democratic Republic of Congo (Heinemann 1958, 1959); Uganda (Corner 1966a; Roberts 1999). ASIA: China (Corner 1966a); India (Khaund & Joshi 2014); Japan (Corner 1966a); Pakistan (Corner 1966a); Turkey (Sesli 1997). EUROPE: Austria (Petersen 1971a); Czech Republic (Kluzák 1994); France (Doassans & Patouillard 1886); Greece (Petersen 1971a); Italy (Petersen 1971a); Lithuania (Urbonas *et al.* 1990), Poland (Adamczyk 1996), Russia (Bulakh 1978; Bulakh & Govorova 2000); Sweden, Switzerland (Petersen 1971a). NORTH AMERICA: Canada (Petersen 1971a); Mexico (Petersen 1971a); U.S.A. (Petersen *et al*. 2014).

Genus *Ramaria* Holmskjold

The genus *Ramaria* is the most diverse genus of the order Gomphales, consisting of nearly 390 species with worldwide documentation, many from European countries (Thind 1961; Rattan & Khurana 1978; Christan & Yorou 2009; Kirk *et al.* 2008; Tedersoo *et al.* 2010). They are either lignicolous or terricolous, with some ectomycorrhizal associations (Humpert *et al.* 2001; Knudsen 2012). The name *Ramaria* was introduced by Holmskjold (1790), but was elevated to a generic level by Donk (1933). Basidiomatal colouration is the key character for the species-level identification of *Ramaria*. Colour ranges from white to yellow, orange, brown, red, brilliant purple and green (Corner 1950, 1970; Knudsen 2012). The other

distinguishing features of the genus *Ramaria* includes dichotomous to polychotomous branched basidiomata, with uninflated, monomitic to rarely dimitic hyphal system with or without clamp-connections, absence of cystidia, with smooth or echinulate, verrucose, rugulose or striate basidiospores with yellow to ochraceous or brown coloured pigmentation and positive hymenial reaction to iron salt (Corner 1950; Corner & Thind 1961; Thind 1961; Marr & Stuntz 1973; Petersen 1975, 1981; Zhishu *et al.* 1993; Humpert *et al.* 2001; Sharma 2013).

Earlier, most fungi with coralloid branching were placed in the genus *Clavaria* (Coker 1923). Though Holmskjold (1790) introduced the name *Ramaria*, it did not formally achieve genus status. Persoon (1797a) described the type species as *R. botrytis* (Pers.) Bourdot and placed it in the genus *Clavaria*. Later, Fries (1821) approved the name *Ramaria*, treating it as a section of the genus *Clavaria*. Donk (1933) gave *Ramaria* its current generic nomenclatural status (Corner 1950, 1970; Donk 1961; Petersen 1968b; Marr & Stuntz 1973; Humpert *et al*. 2001). Initially, *Ramaria* was placed in the family Clavariaceae of the order Aphyllophorales (Corner 1950, 1970; Donk 1964; Fries 1821; Marr & Stuntz 1973; Petersen 1973; Humpert *et al.* 2001). Later studies identified morphological similarities of *Ramaria* (including cyanophilous spore ornamentation, chiastic basidia, hyphal construction, and a positive chemical reaction of the hymenium on treatment with iron salt) with other members of the order Gomphales (Donk 1961, 1964; Eriksson 1954; Petersen 1971; Villegas *et al.* 1999). Different workers (Corner 1970; Hawksworth *et al.* 1995; Donk 1961; Petersen 1988) placed *Ramaria* either under Ramariaceae or Gomphaceae. Variation in macroscopic, microscopic, and macrochemical characters of *Ramaria* has been well studied (Corner 1950, 1970; Donk 1961; Marr & Stuntz 1973; Petersen 1988; Petersen & Zang 1986; Petersen and Scates 1988; Humpert *et al.* 2001).

Molecular phylogenetic studies were also carried out in the genus *Ramaria* to resolve complex generic and species-level taxonomy. Molecular phylogenetic studies support the monophyly of the Gomphales clade (Bruns *et al*. 1998; Hibbett *et al*. 1997; Pine *et al.* 1999) and the placement of the families Lentariaceae, Ramariaceae, Beenakiaceae, and Gomphaceae within the order (Villegas *et al*. 1999; Humpert *et al.*

2001). However, studies by Humpert *et al.* (2001) rejected the monophyly of *Ramaria,* and suggested a ramarioid ancestry for Gomphales. The proposal of a ramarioid ancestry was later supported by Hosaka *et al.* (2006) and Giachini *et al.* (2010).

Infrageneric classification (Corner 1950, 1970; Petersen 1975, 1999; Marr & Stuntz 1973; Knudsen 2012; Hanif *et al.* 2019) of *Ramaria* recognize the following: *R.* subgenus *Ramaria, R.* subgenus *Laeticoloura*, *R*. subgenus *Lentoramaria*, and *R.* subgenus *Echinoramaria*. The subgenera *Ramaria* and *Echinoramaria* are characterized by echinulate spores. Subgenera *Laeticoloura* and *Lentoramaria* have smooth or warted spores. Subgenera *Echinoramaria* and *Lentoramaria* have smaller basidiomata with tomentum or a mycelial mat at the base (Humpert *et al.* 2001).

Humpert *et al.* (2001) in their molecular phylogenetic studies on the genus *Ramaria* and its subgenera indicated that *Ramaria* subgenus *Laeticoloura* and *Ramaria* subgenus *Lentoramaria* were paraphyletic. Currently, only three subgenera, *Laeticoloura*, *Lentoramaria,* and *Ramaria*, are recognized within the genus *Ramaria* (Maneevun *et al.* 2012).

Taxonomic characters

Basidiomata are small to large, cylindrical or rarely flattened (*R. gracilis* (Pers.) Quel.), with polychotomous or dichotomous branching, white, yellow, orange, brown, red, brilliant purple, and sometimes greenish. Flesh is brittle, tough, or gelatinous. White or pale yellowish mycelium present in some species. Basidiospores are small to large, ellipsoid, pale yellow to ochraceous, cinnamon or ferruginous, verruculose or echinulate to striate, rugulose, rarely smooth, generally guttulate. Basidia two to four-spored, not secondarily septate, with or without a basal clamp-connection, sterigmata straight or slightly curved. Hymenium sterile towards the branch apex. Subhymenium composed of inflated, monomitic hyphae with clamp-connections, thin- to thick-walled, narrow interweaving hyphae present in some, cystidia absent (Corner 1950; Thind 1961; Knudsen 2012).

Ecological and economic importance

*Ramari*a species are ectomycorrhizal or saprobic. The known mycorrhizal *Ramaria* species include *R. aurea* (Schaeff.) Quel., *R. botrytis* (Pers.) Bourdot, *R. flava* (Schaeff.) Quel., *R. formosa* (Pers.) Quel., *R. fumigata* (Peck) Corner, and *R. largentii* Marr & D.E. Stuntz. that form association with species of *Abies, Cedrus, Fagus, Larix, Picea, Pinus,* and *Quercus* (Trappe 1962; Baier *et al.* 2006; Di Marino *et al.* 2008; Knudsen 2012). Species such as *R. aurea, R. botrytis*, *R. flava,* and *R. subalpina* K. Das & K. Acharya (Avila *et al.* 2013a; Acharya 2016; Thu *et al.* 2020; Debnath *et al.* 2019) are edible. Bioactive secondary metabolites such as quercetin, chrysin, pinocembrin, protocatechuic and vanillic acids, gallic acid, p-hydroxybenzoic acid, p-coumaric acid, caffeic acid, and cinnamic acid, have been isolated from different *Ramaria* species (*R. flava, R. largentii, R. patagonica* (Speg.) Corner, *R. formosa*, *R. subalpine, R. aurea*) (Gezer 2006; Gursoy *et al.* 2010; Ramesh & Pattar 2010; Liu *et al.* 2013; Khatua *et al.* 2015; Aprotosoaie *et al.* 2017; Toledo *et al.* 2016; Acharya *et al*. 2017b). Carotenoids, ascorbic acid, anthocyanidins, and tocopherols have also been isolated from *Ramaria* (Sharma & Gautam 2017). Antioxidant, antibacterial and anticancerous activities of *R. flava, R. botrytis, R. aurea, R. formosa, R. cystidiophora* (Kauffman) Corner and *R. flaccida* (Fr.) Quél. have been reported (Chung 1979; Yoo *et al.* 1982; Kim *et al.* 1999; Kim & Lee 2003; Gezer 2006; Barros *et al.* 2008; Gursoy *et al.* 2010; Ramesh & Pattar 2010; Bala *et al.* 2011; Gao *et al.* 2012; Liu *et al.* 2013; Rai *et al.* 2013; Zhang *et al.* 2015; Sadi *et al.* 2016; Sharma & Gautam 2017; Acharya 2017; Han *et al.* 2017; Zhou 2017; Dong *et al.* 2020). *R. flava,* exhibit antifungal activity against *Fusarium auenaceum, F. graminearu, Cercosporella albo-maculans,* and *Pseudomonas aeruginosa* (Liu *et al.* 2013; Bhanja *et al.* 2020). Methanolic extract of *R. botrytis* shows hepatoprotective activity against liver toxicity in mice (Kim *et al.* 1999). Ramarin A and B, two novel sesquiterpene derivatives were purified from the methanolic extract of *R. formosa* (Kim *et al.* 2016).

Distribution

Genus *Ramaria* is cosmopolitan in distribution. In a study of the global diversity of ectomycorrhizal fungi, *Ramaria* species were reported from all continents except Antarctica (Tedersoo *et al.* 2010). Known reports are from AFRICA: (Christan & Yorou 2009; Daniëls *et al.* 2012); Congo (Corner 1950); Ethiopia (Gminder *et al.* 2020). ASIA: Azerbaijan (Mustafabayli *et al.* 2021); Indonesia (Corner 1950); India (Thind 1961; Das *et al.* 2016), Himalaya (Thind & Sharda 1985), Ladakh (Dorjey *et al.* 2016), Sikkim (Acharya 2016), Western Ghats (Senthilarasu 2013b), Westbangal (Pradhan *et al.* 2013); China (Zhang *et al.* 2005; Corner 1950); Malasiya, Japan (Corner 1950); Pakistan (Nasim *et al.* 2008; Hanif *et al.* 2019); Thailand (Christan & Hampe 2013). AUSTRALIA: (Young 2009; Young 2014), New Zealand (Petersen 1988); Tasmania (Corner 1950). EUROPE: (Corner 1950; Luszczynski 2008); Romania (Aprotosoaie *et al.* 2017); Russia (Govorova 2003); NORTH AMERICA: (Corner 1950; Petersen & Scates 2000); Dominica, France, Germany, Finland, Argentina, Guadeloupe, Italy, Oregon, Spain, Scotland (Corner 1950); Fennoscandia (Bendiksen *et al.* 2015); Mexico (Cázares *et al.* 2011); Minnesota (Knudsen 2012); Western Washington (Marr & Stuntz 1973); Arknas (Hughes *et al.* 2014); Canada, Nova Scotia (Petersen 1986). SOUTH AMERICA: (Corner 1950; De Toledo & Petersen 1989); Colombia (Hahn & Christan 2002); Czech Republic (Tejklová *et al.* 2014); Guiana (Corner 1950); Poland (Luszczynski 2009).

Genus *Phaeoclavulina* Brinkmann

The genus *Phaeoclavulina* was described by Brinkmann (1897), with *P. macrospora* Brinkmann as the type species. He erected the genus to include species with coralloid basidiomata, ochraceous spores, and bi-sterigmate basidia (*P. macrospora*) (Giachini *et al.* 2019; Avila *et al.* 2020). Brinkmann (1897) added *Phaeoclavulina* to the family Clavariaceae along with *Clavaria, Clavariella, Clavulina*, and *Typhula* (Giachini *et al.* 2019; Avila *et al.* 2020).

In 1923, Overeem described *Phaeoclavulina* as a valid genus, by including *Clavaria zippelii* (Lév.) Overeem (Avila *et al.* 2020). Later, many species belonging to *Cladaria, Cnazonaria, Dendrocladium, Lachnocladium, Penicillaria,*

Phaeopterula, Pistillaria, Pterula, Ramaria, and *Thelephora* were transferred to *Phaeoclavulina* (Giachini *et al.* 2019). However, Corner (1970) considered *Phaeoclavulina* species under the subgenus *Echinoramaria* of *Ramaria*. This was later followed by Petersen (1981) in his monograph on *Ramaria*. He used the name *Phaeoclavulina* as a synonym for the subgenus *Echinoramaria* (Giachini *et al.* 2019; Avila *et al.* 2020).

On the basis of molecular studies, Giachini & Castellano (2011) and Giachini *et al.* (2019) confirmed *Phaeclavulina* as a valid genus and recognized the inclusion of 35 species with ramarioid basidiomata (of *Ramaria* subgenus *Echinoramaria*) and six species with gomphoid basidiomata (Avila *et al*. 2013b; 2020). The pileate forms of *Phaeclavulina* are characterized by unipileate to merismatoid basidiomata with green or violaceous colour, fan- to funnel-shaped pilei that are glabrous to subtomentose, and hymenia that are decurrent with hymenial folds. The ramarioid species of *Phaeclavulina* are characterized by branched basidiomata with colour varying from greenish to violaceous to brown, or orange-red (Giachini *et al.* 2019; Avila *et al.* 2020). Currently, the genus *Phaeoclavulina* consists of 57 species (www.indexfungorum.org, accessed on 1 December 2022).

Taxonomic characters

Basidiomata branched or unipileate, merismatoid, infundibuliform or flabelliform, glabrous or subtomentose, white, yellow, pale to dark orange-yellow, brown, green, olivaceous, blue-green, violet, red cinnamon, brick red or gray. The hymenium is mostly smooth to sublamellate or irregularly wrinkled with decurrent folds in some species. Basidiospores are echinulate or verrucose, subreticulate or reticulate, golden yellow, yellowish brown, orange-brown, or ferruginous in mass, cyanophilic in cotton blue. Basidia are bi-to tetra- sterigmate. Hyphae monomitic with clamp-connections, gleopherous hyphae present. Crystalloid elements present in some species (Giachini *et al.* 2019; Avila *et al.* 2020).

Ecological importance

Most species of *Phaeoclavulina* are saprotrophic, but some species are reported as ectomycorrizal (*P. abietina* (Pers.) Giachini, *P. flaccida* (Fr.) Giachini) (Avila *et al.* 2020; Herrera *et al*. 2002; Norvell & Exeter 2004; Dong-Hun *et al.* 2003; Avila *et al.* 2013).

Distribution

The genus *Phaeoclavulina* has a cosmopolitan distribution, is abundant in the tropics and subtropics, but, only with a few reports from temperate regions (Giachini 2004; Gonzalez-Avila *et al*. 2013b, 2020; Giachini *et al.* 2019). AFRICA: Uganda (Petersen 1976). ASIA: North Borneo (corner 1966a); Malaysia (Corner 1950, 1966a); Thailand (Wannathes *et al*. 2018); India, Maharashtra (Senthilarasu (2013b), Madhya Pradesh (Thind & Anand 1956). AUSTRALIA (Petersen 1981). EUROPE (Kriz *et al*. 2019); Maltese Islands (Misfud 2019). NORTH AMERICA: Mexico (Gonzalez-Avila *et al.* 2013b). SOUTH & CENTRAL AMERICA (Petersen 1971a, 1981); Trinidad & Tobago (Corner 1968); France, Guadeloupe (Corner 1966a); The Solomon Islands (Corner 1968); Amazon, Brazil, Mato Grosso States (Corner 1968).

2.8.**ORDER RUSSULALES** P.M. Kirk, P.F. Cannon & J.C. David

The order Russulales is a highly diverse group in Agaricomycetes, comprising of about 2000 species distributed in 83 genera and 13 families (Kirk *et al*. 2008; Wu *et al.* 2020). The Russulales members have a variety of basidiomal morphologies, including resupinate, clavarioid, pileate, and gasteroid, as well as hymenophore configurations ranging from smooth to poroid, hydnoid, and lamellate (Miller *et al.* 2006; Wu *et al.* 2020). Members of the order Russulales share microscopic characters such as the presence of gloeocystidia and amyloid basidiospores (Larsson & Larsson 2003). Russuloid fungi are primarily saprobes. Ectomycorrhizal species, root parasites, and insect symbionts are also observed (Miller *et al.* 2006).

Russulales are a well-studied monophyletic group, though with some unresolved taxonomic identities (Hibbett *et al*. 1997; Hibbett & Binder 2002; Larsson *et al.* 2004; Miller *et al.* 2006; Liu *et al.* 2017; Wu *et al*. 2020). According to Hibbett & Thorn (2001), the russuloid clade includes taxa that were formerly placed in the families Auriscalpiaceae Maas Geest., Bondarzewiaceae Kotl. & Pouzar, Clavicoronaceae Corner, Corticiaceae Herter *sensu lato*, Echinodontiaceae Donk, Hericiaceae Donk, Lachnocladiaceae DA Reid, Peniophoraceae Lotsy, Polyporaceae Corda, Russulaceae Lotsy, and Stereaceae Pila`t. Currently, the order contains 2000 described species in 83 genera and 13 families (Kirk *et al.* 2008; Wu *et al.* 2020).

Peniophoraceae Lotsy

Peniophoraceae is a family in the order Russulales with a cosmopolitan distribution (Cannon & Kirk 2007). Members are primarily saprotrophic, but wood rotting species are also known (Cannon & Kirk 2007; Gou *et al*. 2021). The family is characterized by the presence of papillate skeletal hyphae (*Baltazaria* Leal-Dutra, Dentinger & G.W. Griff.), dicophyses (*Lachnocladium* Lev.), skeletodendrohyphidia (*Baltazaria* Leal-Dutra, Dentinger & G.W. Griff.), lamprocystidia (*Duportella* Pat., *Peniophora* Cooke), or gloeocystidia (*Lachnocladium* Lev.). Phylogenetic studies in Russulales, reveal the family Peniophoraceae to be a strongly supported clade (Larsson & Larsson 2003; Miller *et al.* 2006; Leal-Dutra *et al.* 2018; Liu & He 2018). The family includes 352 species in 15 genera (*Amylofungus* Sheng H. Wu,

Asterostroma Massee, *Baltazaria* Leal-Dutra, Dentinger & G.W. Griff., *Dendrophora* (Parmasto) Chamuris, *Dichostereum* Pilat, *Duportella* Pat., *Entomocorticium* H.S. Whitney, Bandoni & Oberw., *Gloiothele* Bres., *Lachnocladium* Le´v., *Licrostroma* P.A. Lemke, *Peniophora* Cooke, *Sceptrulum* K.H. Larss., *Scytinostroma* Donk, *Vararia* P. Karst., and *Vesiculomyces* E. Hagstr. (He *et al.* 2019; www.indexfungorum.org). All the genera in the family *Peniophoraceae* are corticioid, except for the coralloid genus *Lachnocladium* and the insect symbiont *Entomocorticium* (Liu *et al.* 2018).

Genus *Lachnocladium* Lèveillè

The genus *Lachnocladium* is the only clavarioid genus in the family Peniophoraceae. The genus is restricted to the tropics (Corner 1952c; Perez-Moreno & Villareal 1989). *Lachnocladium* incorporates about 67 species (www.indexfungorum.org, accessed on 28 November 2022). The genus is characterized by the presence of ramified basidiomata, dichophyses, smooth basidiospores, presence of gloeocystidia, uninflated hyphae, and the absence of hyphal clamp-connections (Corner 1950).

Lachnocladium was proposed by Lèveillè (1844), with *Lachnocladium brasiliensis* Lèv. as the type species (Corner 1950; Donk 1954). Previously, all the clavarioid species with a leathery texture were included in this genus (Perez-Moreno & Villareal 1989). But Corner (1950) restricted the genus to only those having dychophidia (Donk 1954; Perez-Moreno & Villareal 1989). Donk (1954) placed the genus in the family Hymenochaetaceae. Reid (1965) included *Lachnocladium* in the family Lachnocladiaceae (Petersen 1971b; Moreno & Villareal 1989). Corner (1952) recommended the placement of *Parapterulicium* in Lachnocladiaceae based on the presence of dichophyses and gloeocystidia. But due to the small filiform basidiomes and branching pattern, the latter was placed in the family Pterulaceae.

The placement of Lachnocladiaceae in the russoloid clade was supported by phylogenetic studies **(**Hibbett & Donoghue 1995; Hibbett *et al*. 1997; Larsson & Larsson 2003; Leal-Dutra *et al.* 2018). Larsson & Larsson (2003) added the genera *Peniophora*, *Gloiothele*, and *Vesiculomyces* to the Lachnocladiaceae. However,

except for a few species in *peniophora*, the other two genera do not have dichohyphidia. Binder *et al.* (2005) recovered the Lachnocladiaceae clade in their phylogenetic studies but did not include the genus *Lachnocladium* (Leal-Dutra *et al.* 2018). Following the recent molecular phylogenetic studies on the order Russulales, Larsson & Larsson (2003), Miller *et al.* (2006), and Leal-Dutrra *et al.* (2018) suggested the placement of *Lachnocladium* in the family Peniophoraceae.

Taxonomic characters

Basidiomata with ramified branches that are slightly tomentose, colour ranges from yellowish brown to deep brown. Basidiospores are smooth. Hyphae dimitic, dichophyses and gloeocystidia present, and hyphal clamp-connections absent (Burt 1919; Corner 1950).

Ecological and economic importance

The genus *Lachnocladium* is reported as saprotrophic (He *et al.* 2019). *Lachnocladium* species have been reported to have phytochemical activities. A multicopper oxidase laccase, which catalyzes the oxidation of various phenolic substrates, was obtained from a *Lachnocladium* species (Wuyep *et al.* 2012). It was reported that the biological pretreatment of corn cobs and sugarcane bagasse by fermentation with *Lachnocladium* species significantly improved the nutritive value of both (Olagunju *et al.* 2013; 2014).

Distribution

The genus *Lachnocladium* has a tropical distribution **(**Corner 1952c; Moreno & Villareal 1989). AFRICA**:** Cameroon (Leal-Dutra *et al.* 2018); Jamaica (Larsson & Larsson 2003). ASIA: India, West Bengal, Meghalaya (Berkeley 1856), Uttarakhand (Hennings 1901). NORTH AMERICA: Cuba (Burt 1919), Mexico (Moreno & Villareal 1989). SOUTH AMERICA: Brazil. USA: Pennsylvania, New Jersy, West Virginia (Burt 1919), Puerto Rico (Leal-Dutra *et al.* 2018).

2.9.**ORDER TRECHISPORALES** K. H. Larsson

The order Trechisporales was described by Hibbett *et al.* (2007), typified by the genus *Trechispora* based on molecular evidence (Larsson *et al*. 2004; Binder *et al.* 2005; Matheny *et al*. 2007; Hibbett *et al.* 2007, 2014; Liu *et al.* 2022). It is a taxon-poor order when compared with most other orders within Agaricomycetes (Liu *et al.* 2022). Larsson (2007) in his molecular phylogenetic classification of the corticioid fungi, recognized the genera *Fibrodontia* Parmasto, *Cristelloporia* I. Johans. & Ryvarden, *Dextrinocystis* Gilb. & M. Blackw., *Dextrinodontia* Hjortstam & Ryvarden, *Litchauerella* Oberw, *Luellia* K.H. Larss. & Hjortstam, *Hydnodon* Banker, *Porpomyces* Jülich, *Subulicystidium* Parmasto, *Subulicium* Hjortstam & Ryvarden, *Trechispora* P. Karst *and Tubulicium* Oberw., in the family Hydnodontaceae, and the genus *Sistotremastrum* J. Erikss in the formally unnamed family Sistotremastrum (Telleria *et al*. 2013; Hibbett *et al.* 2014). Telleria *et al*. (2013), in their phylogenetic study of the order Trechisporales, confirmed the placement of the genus *Brevicellicium* in Hydnodontaceae. Hjortstam & Ryvarden (2008) segregated a new genus, *Brevicellopsis*, from *Brevicellicium* to be included in this family. Birkebak *et al.* (2013), in their systematic studies on the family Clavariaceae, found that the clavarioid genus *Scytinopogon* nested within the Trechisporales. The molecular phylogenetic studies by Telleria *et al*. (2013) supported the placement of two families: Hydnodontaceae and an informal *Sistotrematrum* family, and concluded that the Trechisporales is a monophyletic group. A recent phylogenetic study in Trechisporales by Liu *et al*. (2022) excluded *Sertulicium* and *Sistotremastrum* from Trechisporales and placed them in the new family Sistotremastraceae within the new order Sistotremastrales. Also, a new genus, *Allotrechispora*, which is segregated from *Trechispora*, is included in Hydnodontaceae. The genera *Boidinella*, *Litschauerella* and *Sphaerobasidium* were also excluded by Liu *et al*. (2022) from the order Trechisporales, and the genus *Scytinopogon* is synonymized with *Trechispora.*

The majority of species in the order Trechisporales belong to the highly diverse genus *Trechispora* that mostly includes corticioid fungi and a few clavarioid species. Currently, the order Trechisporales consists of one family (Hydnodontaceae)

and 12 genera (*Allotrechispora, Brevicellicium, Brevicellopsis, Dextrinocystis, Fibrodontia, Luellia, Porpomyces, Pteridomyces, Subulicystidium, Suillosporium, Trechispora*, and *Tubulicium*) (Liu *et al*. 2022).

Hydnodontaceae Jülich

The family Hydnodontaceae was proposed by Jülich (1981), with *Hydnodon thelephorus* (Lev.) Banker as the type species. It is the only family in the order Trechisporales, with 12 genera and approximately 100 species (Telleria *et al.* 2013; Hibbett *et al.* 2014). The majority of the genera in the family Hydnodontaceae are comprised of corticioid fungi, with the exception of a few clavarioid taxa in the genus *Trechispora* and the polypore genus *Porpomyces* (Hibbett *et al.* 2014). An anamorphic stage also exists for some species in the family, such as *Aegerita tortuosa* (as *Subulicystidium longisporum* (Pat.) Parmasto in www.indexfungorum.org) for *Subulicystidium,* and *Osteomorpha* for *Trechispora* (Hibbett *et al.* 2014). Basidiomata forms in the Hydnodontaceae range from corticioid to clavarioid (*Trechispora*), stipitate hydnoid (*Hydnodon thelephorus*), and resupinate polyporoid (*Porpomyces*, *Trechispora*) (Hibbett *et al.* 2014). The family is characterized by monomitic hyphae with nodose-septation and clamp-connections, rarely with dimitic hyphae, basidia with four to six sterigmata, smooth or ornamented basidiospores. Cystidia may or may not be present. If present, with prominent subulate cystidia. Calcium oxalate crystals are present in some species (Hibbett *et al.* 2007; Hibbett *et al*. 2014).

Jülich (1982) placed the genera *Brevicellicium* and *Trechispora* in the family Hydnodontaceae. Larsson's (2007) molecular phylogenetic studies confirmed this arrangement and placed the family in the order Trechisporales. He added the genera *Brevicellicium, Fibriciellum, Fibrodontia, Luellia, Porpomyces, Subulicystidium, Trechispora,* and *Tubulicium* to the family. In addition, he listed the genera *Dextrinocystis, Dextrinodontia,* and *Litchauerella* to be included in Hydnodontaceae. Liu *et al.* (2019) in his phylogenetic studies on corticioid species, confirmed the placement of *Dextrinocystis* in Hydnodontaceae. Molecular analysis by Telleria *et al.* (2013) confirmed the genus *Brevicellicium* within Hydnodontaceae. Recently, Larsson *et al.* (2011) and Birkebak *et al.* (2013) added the clavarioid genus

Scytinopogon to the family Hydnodontaceae. Liu *et al.* (2022) added a new genus *Allotrechispora* and synonymized the genus *Scytinopogon* with *Trechispora*. Currently, the family Hydnodontaceae is comprised of 12 genera (Liu *et al.* 2022).

Genus *Trechispora* P. Karst.

The genus *Trechispora* is the largest genus in the order Trechisporales, with 87 accepted species (Liu *et al.* 2022). The genus mostly consists of corticioid fungi, with few exceptions having clavarioid (like *T. dealbata* (Berk.) L.W. Zhou & S.L. Liu, *T. longiramosa* S.L. Liu, G. He, Shuang L. Chen & L.W. Zhou, *T. papillosa* (Corner) Meiras-Ottoni & Gibertoni, *T. robusta* (Rick) L.W. Zhou & S.L. Liu, *T. scaber* (Berk. & M.A. Curtis) L.W. Zhou & S.L. Liu*)* and polyporoid (*T. daweishanensis* C.L. Zhao and *T. xantha* C.L. Zhao) basidiomata (Larsson 2007; Liu *et al*. 2022). The genus *Trechispora* is characterized by smooth, odontioid, hydnoid, or poroid hymenophores, monomitic or dimitic hyphal systems with clamp-connections, ampullaceous septa, and smooth to verrucose, angular basidiospores. (Larsson 1992; Larsson *et al.* 2004).

The genus *Trechispora* was described by Karsten (1890) to accommodate a single species, *T. onusta* P. Karst., with resupinate basidiomata and a poroid hymenophore. Liberta (1973) reported 21 species in the genus *Trechispora,* and most were reduced to synonyms later (Larsson 1996). Phylogenetic analyses (Larsson *et al.* 2004; Binder *et al.* 2005; Hibbett *et al.* 2007; Larsson 2007) placed *Trechispora* in the order Trechisporales. A species with stipitate basidiomata and a hydnoid hymenophore, *Hydnum thelephorum* Lev., was placed in *Trechispora* based on phylogenetic analysis (Ryvarden 2002; Larsson *et al.* 2011; Birkebak *et al.* 2013; Chikowski *et al*. 2020). Certain clavarioid species of the genus *Scytinopogon* nested in the *Trechispora* clade in various phylogenetic studies (Larsson 2007; Birkebak *et al*. 2013; Desjardin & Perry 2015; Chikowski *et al.* 2020; Meiras-Ottoni *et al.* 2021). The genus *Scytinopogon* also shows micromorphological similarities with *Trechispora* (Julich 1981; Larsson 1992; Meiras-Ottoni *et al.* 2021). Birkebak *et al.* (2013) conducted a systematic study on the family Clavariaceae and showed the phylogenetic affinity of *Scytinopogon* with the Trechisporales. Larsson *et al.* (2011)

confirmed the phylogenetic affinity between *Scytinopogon* and Trechisporales (Birkebak *et al.* 2013). Whereas, Desjardin & Perry (2015) did not support the *Scytinopogon-Trechispora* clade. Meiras-Ottoni (2021) conducted a phylogenetic study using nuc rDNA ITS and nuc 28S rDNA regions and recovered strong support for the *Trechispora-Scytinopogon* clade. Based on these observations, many species earlier considered in *Scytinopogon* were formally transferred to *Trechispora* (*T. chartacea, T. havencampii, T. minispora, T. pallescens,* and *T. papillosa*) by Meiras-Ottoni *et al.* (2021).

Recently, Liu *et al.* (2022) conducted a phylogenetic study of the order Trechisporales and segregated a new genus, *Allotrechispora*, from *Trechispora*. He also supported the synonymization of the genus *Scytinopogon* within *Trechispora.* However, those species of *Scytinopogon* which have not been formaly recombined in to the genus *Trechispora* have been retained as such. Such species may be transferred to *Treschispora* at a later stage, after more studies. According to www.indexfungorum.org (accessed on 17 November 2022), three species of *Scytinopogon* (*S. cryptomerioides, S. echinosporus*, and *S. parvus*) are retained as such.

Taxonomic characters

Basidiomata are mostly resupinate, few with stipitate to coralloid, hymenophore smooth, granular to hydnoid and poroid. Basidiospores are angular, ellipsoid, mostly verrucose or aculeate to rarely smooth. Basidia are small and cylindrical. Hyphae monomitic to dimitic, with clamp-connections, ampullate septa present (Larsson 1992; Chikowski *et al.* 2020; Meiras-Ottoni *et al*. 2021; Luo & Zhao 2022).

Ecological importance

The genus *Trechispora* are saprotrophic (Hibbett *et al.* 2014), with some (*T. thelephora*) exhibiting ectomycorrhizal associations (Albee-Scott & Kropp 2010).

Distribution

The genus *Trechispora* has a world-wide distribution (Luo & Zhao 2022). AFRICA: Canary island (Corner 1950; Ryvarden & Liberta 1978; Desjardin & Perry 2015), La Réunion Island (Ordynets *et al.* 2015). AUSTRALIA: Fiji, Solomon Island (Corner 1950). ASIA: China (Xu *et al.* 2010; Zhao & Zhao 2021; Zong *et al.* 2021; Luo & Zhao 2022); Java; Sumatra; Philippines (Corner 1950); India (Thind 1961; Asit baran 1991; Acharya 2012; Verma & Pandro 2018). EUROPE: (Miettinen & Larsson 2006); Germany (Kamke 2021); France (Trichies & Schultheis 2002); Russia (Ruokolainen & Kotkova 2016). NORTH AMERICA: Mexico (Valenzuela *et al.* 2004; Garcı´a Sandoval *et al.* 2004; Ramírez-López 2012); Spain (Jorge 1980); Finland (Kunttu *et al.* 2015). SOUTH AMERICA: Brazil (Corner 1950; Meiras-Ottoni *et al.* 2020; Chikowski *et al.* 2020; Furtado *et al.* 2021) USA, Panama, Bolivia, Puerto Rico (Corner 1950; Albee-Scott & Kropp 2010).

2.10. **TREMELLODENDROPSIDALES** Vizzini

Tremellodendropsidales is a monotypic order in Agaricomycetes, with a single family (Tremellodendropsidaceae Jülich) and a single genus (*Tremellodendropsis* (Corner) D.A. Crawford) (Leacock 2018; www.indexfungorum.org, accessed on 10 November 2022). It is an ectomycorrhizal order whose members are associated with a wide range of angiosperm species (Truong *et al.* 2017). The order is characterized by light-coloured basidiomata that are subcoriaceous to tough in consistency, erect, with terete to flattened branches, smooth basidiospores, basidia with sulcate divisions at the apex, and a monomitic hyphal system with clamp-connections (Vizzini 2014). The order Tremellodendropsidales was proposed by Vizzini (2014). Berbee (2016) confirmed Tremellodendropsidales as a divergent order within the class Agaricomycetes using molecular evidence.

Currently, the order includes the family Tremellodendropsidaceae and a single genus, *Tremellodendropsis*, with seven species (www.indexfungorum.org, accessed on 10 November 2022).

Tremellodendropsidaceae Jülich

The family Tremellodendropsidaceae was proposed by Jülich (1984), with a single genus, *Tremellodendropsis* (KshamaTripathi *et al.* 2022). Berbee *et al.* (2016) studied the phylogenetic placement of Tremellodendropsidaceae in the order Tremellodendropsidales and proposed the group as a unique Agaricomycete lineage.

Genus *Tremellodendropsis* (Corner) D.A. Crawford

Tremellodendropsis is a clavarioid genus in the family Tremellodendropsidaceae, consisting of seven described species (www.indexfungorum.org, accessed on 10 November 2022). It was proposed by Corner (1953) as a subgenus of *Aphelaria* to accommodate the species *Tremellodendropsis tuberosa* (Corner 1966b; Berbee *et al.* 2016; KshamaTripathi *et al.* 2022). The genus is characterized by light-coloured basidiomata with erect, clavarioid branching, false septate basidia with clamp-connection, smooth spores, and monomitic hyphal systems with clamp-connections (Corner 1966, 1970).

T. tuberosa was first described as *Merisma tuberosa* (Greville 1825) and later transferred to *Aphelaria tuberosa* by Corner (1950) (Berbee *et al.* 2016;

KshamaTripathi *et al.* 2022). Corner's concept of the genus *Aphelaria* includes species with clavarioid basidiomata and with or without septate basidia. But the diversity in the basidial form led him to construct a new subgenus in *Aphelaria*, *Tremellodendropsis* (Berbee *et al.* 2016). Corner (1950) placed species without basidial septations and clamp-connection in the genus *Aphelaria,* subgenus *Aphelaria,* and those with septate basidia and clamp-connection in the subgenus *Tremellodendropsis* (Corner 1966). Later, Crawford (1954) elevated *Tremellodendropsis* to the generic level by including more species. *T. tuberosa* (Grev.) Crawford was recognized as the type species (Corner 1966; Berbee *et al.* 2016).

The placement of *Tremellodendropsis* (in either orders Auriculariales and Tremellales) had been controversial. Partly septate basidia are one of the microscopic characters used to identify the *Tremellodendropsis* species. This feature led to the consideration of the genus as heterobasidiomycetous. Wei & Oberwinkler (2001) placed *Tremellodendropsis* in the order Auriculariales. The placement of *Tremellodendropsis* in Tremellodendropsidales has been resolved on the basis of the study by Berbee *et al*. (2016).

Taxonomic characters

Basidiomata are erect, branched, dull white to greyish or pale brown in colour. Basidia are sulcately divided at the apex or with false septum, and with basal clamp-connection. Basidiospores are smooth, subglobose to ovoid or ellipsoid. Hyphal system is monomitic, with clamp-connections (Corner 1966; 1970).

Ecological importance

T. tuberosa is reported as an ectomycorrhizal fungus which is associated with a wide range of angiosperms (Truong *et al.* 2017).

Distribution

The genus *Tremellodendropsis* have temperate and tropical reports. AFRICA (Petersen 1967c); Madagascar (Corner 1970). ASIA: Boreno (Corner 1970); India (KshamaTripathi *et al.* 2022); Indonesia, Sumatra, Java (Corner 1970). AUSTRALIA: (Corner 1970) New Zealand (Crawford 1954; Petersen 1987). NORTH AMERICA: Costa Rica (Kisimova-Horovitz *et al*. 2000). SOUTH AMERICA: Brazil; (Corner 1970).

3. MATERIALS AND METHODS

3.1. STUDY AREA - KERALA

Physiography

Kerala, one of the biodiversity-rich states in India, is unique in its geographical and physiological features. It is the southernmost state of India, covering 1.18% of the total area of the country (Thomas 2000), with a total geographical area of 39,000 km^2. Kerala lies between $74^0$52'–$77^0$22' East Longitudes and $8^0$18'– $12^0$48' North Latitudes (Kumar *et al.* 2018), bordered by the Arabian Sea of the Indian Ocean on the west and the mountains of the Western Ghats on the east (Balasubramanian 2017). 72.08% (28008 km^2) of the total geographical area of Kerala is included in the Western Ghats (Arisdason & Lakshminarasimhan 2014). The highest peak in India after the Himalayas, the Anamudi peak, lies in the Idukki division of the Western Ghats (Arisdason & Lakshminarasimhan 2014). Based on the topography, Kerala is divided into three geographical regions (Aravindakshan & Manimohan 2015). 1) the highlands formed by the Western Ghats on the eastern side with dense evergreen forests (600–1800 m high), 2) the central midlands lying between the mountains and lowlands with hills and valleys (300–600 m high), and 3) the lowlands or coastal area composed of the river deltas, backwaters, and canals (6-300 m high) (Thomas 2000; Shijitha *et al.* 2020). These coastal belts extend up to 590 km with a network of 44 rivers, 34 lakes, and 11 backwaters (Joshi 2012). There are six geophysical areas. They are forests, marshes, mangroves, ponds, seashores, and deltas (Sreedharan 2004).

Vegetation

Kerala has a total recorded forest cover of 11,524.149 km^2 (https://forest.kerala.gov.in). The geographical area is a blend of a variety of vegetation and forest types. Champion and Seth (1968) recognized 26 forest types in Kerala, of which the major ones are the tropical wet evergreen and semi-evergreen forests, moist deciduous forests, dry deciduous forests, shola grasslands, plantations,

wetlands, and sacred groves. 3213.24 km^2 of forest area in the state is under the Protected Areas Network (Arisdason & Lakshminarasimhan 2014). The southern districts cover 51% of the total forest area, and the remaining 49% is in the central and northern regions. Idukki, Palakkad, and Pathanamthitta districts have the largest area under forest cover. Alappuzha is the only district with the least forest cover (Balasubramanian 2017).

The Western Ghats represent one of the world's 18 hot spots of biodiversity and are considered to be a repository of endemic, rare and endangered flora and fauna (Balasubramanian 2017). The state shelters 5094 species of flowering plants under 1537 genera (Sasidharan 2012). Out of these, 4078 are indigenous, of which 1568 are endemic to India, and of these, 865 are endemic to the Western Ghats. The endemic angiosperm flora of Kerala is very rich. Of the 865 endemics of the Western Ghats, 237 species are endemic to Kerala. About 5% of the flora falls under one or another IUCN Red List category (Nayar *et al*. 2008). It has been found that 1170 species occurring in the state have medicinal properties. Out of these, 1096 species are indigenous and the rest 74 are exotic (Nayar *et al.* 2008). The unique biological diversity of Kerala is also represented by its 1500 sacred groves. The size of the sacred groves in Kerala varies from as small as one cent to 20 hectares or more (Padmanabhan 2005). The vegetation in sacred groves are flourishing with luxuriant flora and fauna. They are conserved in the name of religion and culture (Sing *et al.* 2017; Chandrashekaran & Sankar 1998; Rajendraprasad *et al.* 2000). Different types of soils are found in Kerala, such as coastal alluvium, acid saline, acid sulphate, laterite, red soil, hill soil, black cotton soil, and forest soil (Nayar 2010).

As part of conservation of the biodiversity, there are two Biosphere Reserves (Nilagiri Biosphere Reserve and Agasthyamalai Biosphere Reserve), five National Parks (Anamudishola National Park, Eravikulam National Park, Silent Valley National Park, Mathikettan Shola National Park and Pampadumshola National Park) and 17 Wildlife Sanctuaries (Aralam Wildlife Sanctuary, Chinnar Wildlife Sanctuary, Chimmony Wildlife Sanctuariy, Choolanur Pea Fowl Sanctuary, Idukki Wildlife Sanctuary, Karimpuza Wildlife Sanctuary, Kottiyoor Wildlife Sanctuary, Kurinjimala

Wildlife Sanctuary, Malabar Sanctuary, Mangalavanam Bird Sanctuary, Neyyar Widlife Sanctuary, Parambikulam Wildlife Sanctuary, Peechi-Vazani Wildlife Sanctuary, Peppara Wildlife Sanctuary, Periyar Wildlife Sanctuary, Shendurney Wildlife Sanctuary, Thattekad bird Wildlife Sanctuary, and Wayanad Wildlife Sanctuary) and one Community Reserve (Kadalundi-Vallikunnu Community Reserve) in Kerala (http:/forest.kerala.gov.in/index.php?option=com_content&view=article&id=205&Itemid, accessed on January 2022).

Climate

Kerala, which lies in the tropical region with intermittent wet and dry periods, gets most of its rainfall during the two monsoon seasons: the south-west monsoon season, starting from early June and extending up to September; and the north-east monsoon season, occurring in the period of October-December (Kumar *et al.* 2019). The south-west monsoon provides most of the rainfall and contributes to nearly 60% of the annual precipitation (Shirin & Thomas 2016). The south-west monsoon hits Kerala's coast during the month of June and May continue till the end of August. A comparatively less rainy interval occurs in September and October during the north-east monsoon seasons, also known as the retreating monsoon. Extending from September to December, it brings comparatively very less rainfall (Leelavathy & Ganesh 2000). The state receives a mean annual rainfall of 300 cm spread over 120-140 rainy days annually. It varies from 100 cm to 760 cm in hilly areas. December to February are considered winter months, characterized by minimum rainfall and a somewhat cloudy condition. The dry season in Kerala starts at the end of January and extends till June. It may vary according to the variation in the seasonal monsoon period. The mean annual temperature ranges between 24°C and 37.5°C in the plains and midlands of Kerala and between 10°C and 32°C in the hills. The average maximum daily temperature is around 37°C and it rises to about 40°C to 45°C during the hot months of March, April and May. The mean relative humidity varies between 85% and 95% during June and lowers to 70% in summer months (Simon & Mohankumar 2004; Sasidharan 2006).

FIGURE 1: Map of Kerala State, India, showing major collection localities

3.2. FIELD STUDY AND SPECIMEN COLLECTION

Clavarioid basidiomata for the study were collected from Kerala, from September 2017 to August 2022. Major collections were made during the south-west monsoon (June to September) and north-east monsoon (October to December). Collection areas include forests such as Reserve forests, territorial forests of the districts Kannur, Kasargod, Malappuram, Thrissur, Wayanad, Palakkad, Kollam, Thiruvananthapuram, Idukki, and non-forest areas such as sacred groves of Kozhikode district (Poilkavu, Thurayil Kavu and Vallikkattu Kavu), Kannur district (Neeliyar Kottam and Poongottu Kavu), Kasargod district (Edayilakkadu Kavu and Mannampurathu Kavu), Ernakulam district (Iringol Kavu), botanical gardens and private lands. Major collection areas are shown in FIGURE. 1. Most basidiomata were obtained from the soil, but some were collected from leaf litter and dead and decayed wood logs. Basidiomata of different stages were collected from the field whenever possible. Care was taken to collect the basidiomata without excluding the base.

3.3. MORPHOLOGICAL CHARACTERIZATION

Macroscopic characters were recorded from freshly collected specimens. Macro photographs were taken from the field itself, whenever possible. Photographs were taken using the SONY CYBERSHOT DSE-HX400V CAMERA and mobile cameras from LENOVO K8 PLUS and VIVO V20. Collection data indicating habit, habitat, collection date, localities, and associated trees/plants were prepared for each specimen. Macroscopic characters of the basidiomata such as colour, size, and shape, colour change on bruising, odour and surface features, were noted. A LABOMED CXM2 stereomicroscope was used to examine and record the macroscopic features of the basidiomata, such as the surface features (glabrous, grooved, pruinose, pubescent, tomentose or strigose), branching pattern (dichotomous or polychotomous), and context (fleshy or brittle). Macrochemical tests using 5% KOH and 10% $FeCl_3$ were carried out on fresh specimens, and colour changes were noted.

Fresh and dried basidiomata were used for microscopic examination. Thin sections from different regions of the basidiomata were taken using razor blades and were placed on a microscopic slide. The sections were stained using an aqueous

mixture of 1% phloxine and 1% congo red. A 5% aqueous solution of KOH was used for removing excess stains from the tissue. Stained specimens were mounted in 5% KOH. The specimens were also mounted in tap water to note the natural pigmentation of hyphae and basidiospores. Reagents such as Melzer's and 1% lactophenol cotton blue were also used to note the colour reaction of basidiospores. Calibrated LABOMED Lx400 and Magnus MXi21LED compound light microscopes were used for observing the microscopic features and for taking the measurements. Size, arrangement, wall-thickness, clamp-connections (when present), and types of hyphae were noted. Characters of cystidia (when present), shape, size, and presence of oil contents (uniguttulate or multiguttulate), presence of basidial clamp-connection (when present), size, shape, and number of sterigmata were noted. Twenty basidiospores were measured for obtaining the spore dimensions, mean, range of spore quotient (Q, length/width ratio) and its mean value (Qm). Shape, size, ornamentation, wall thickness, length of the apiculus, and colour of the basidiospores were noted. Microscopic photographs of the observed basidiomata were taken using AMSCOPE digital microscope camera attached to the compound microscope. Microscopic photographs were processed using the IS CAPTURE software. Based on macroscopic and microscopic observations, taxonomic description sheets were prepared for all taxa examined. The descriptions of multiple collections of each species were later compiled. Photographic plates were prepared using the ADOBE PHOTOSHOP CS3.

All collections were dried in hot air oven at 65^{o} and were transferred to paper packets labelled with collection number and collection details. For fungarium storage these packets were vacuum sealed using the modified method of Pradhan *et al.* (2015). All collections obtained during the study were properly packed and sealed and have been deposited at the Zamorin's Guruvayurappan College herbarium (ZGC), Kozhikode, and at the Central National Herbarium (CAL), Kolkata.

The work "Monograph of *Clavaria* and Allied Genera" (Corner 1950), was referred for technical terminology and methodology. Species identifications were done using taxonomic keys available in monographs like, the "Monograph of

Clavaria and Allied Genera" (Corner 1950), "Clavariaceae of India" (Thind 1961), "Supplement to a Monograph of *Clavaria* and Allied Genera" (Corner 1970), "The clavarioid fungi of New Zealand" (Petersen 1988). Publications in journals and other sources were also used for taxonomic identification, phylogeny and distribution details. For latest information on taxonomic and systematic positions, the online resource *Index Fungorum* (www.indexfungorum.org) was referred.

The higher-level classification and taxonomic concepts of the orders and genera followed in this study were that of Dentinger and McLaughlin (2006), Kautmanová *et al.* (2012a), Birkebak *et al*. (2013), Vizzini (2014), Hibbet *et al.* (2014), Olariaga *et al*. (2015; 2020), Chikowski *et al.* (2020), Leal-Dutra *et al.* (2020), and Liu *et al.* (2022).

3.4. PURE CULTURE ESTABLISHMENT

Potato Dextrose Agar (PDA) medium (composition: Potato-200 g, Dextrose-18 g, Agar-20 g, tap water-1 L) was used for cultural isolation from the freshly collected specimens. To avoid bacterial contamination, a pinch of chloramphenicol or streptomycin were added. The medium dispensed in the petri plates were allowed to solidify. Then a small piece from the fresh basidiomata was taken using sterile surgical blades and placed it on the petri plate containing the medium. Mycelial growth from the tissue was observed after 1-2 days. After getting proper mycelial growth, they were subcultured. For subculturing, PDA medium in screw cap test tubes or 1.5 ml Eppendorf tubes were used. The sub cultured tubes labelled with collection number, and date of sub culturing were maintained in short term low temperature storage method in refrigerator. All the pure cultures obtained have been catalogued and maintained in the Fungal Diversity laboratory of the Zamorin's Guruvayurappan College.

3.5. MOLECULAR CHARACTERIZATION

For DNA extraction, small tissues from fresh basidiomata were taken whenever possible. Dried tissues were used when fresh samples were not available. REDExtract-N-Amp^{TM} PCR kit (www.sigma-aldrich.com) was used for DNA

extraction from the tissues of basidiomata. The manufacturer's instructions were strictly followed whenever the kit was used. For some collections, DNA was extracted using the procedure of Izumitsu *et al*. (2012). Approximately 5 to 6 mm pieces were taken from the basidiomata and transferred to a 1.5 ml microfuge tube containing 100 µl TE buffer. The tubes containing the tissues were microwaved for 1 minute at 600W. Then the tubes were stored at room temperature for 30 seconds. This was again microwaved for another 1 min at 600W. After that the tubes were cooled at -20^{o} C for 10 min. Finally, the tubes were centrifuged at 10,000 rpm for 5 min, and then the supernatants were used for PCR amplification.

PCR amplification of the ITS region was carried out using the universal primers, ITS1F (5'TCCGTAGGTGAACCTGCGG 3') and ITS4R (5' TCCTCCGCTTATTGATATGC 3') (Gardes & Bruns 1993; White *et al.* 1990), LSU gene region using the primers LROR (5' ACCCGCTGAACTTAAGC 3') and LR5 (5' TCCTGAGGGAAACTTCG 3') (Binder & Hibbett 2002), and RPB2 gene region using the primers fRPB2-5F (GAYGAYMGWGATCAYTTYGG) and bRPB2-7R2 (ACYTGRTTRTGRTCNGGRAANGG) (Matheny 2006). The PCR amplification cycle of the ITS and LSU regions consisted of 30 sec at 98^{o} C; 40 cycles of 5 sec at 98^{o} C, 10 sec at 60^{o} C, 50 sec at 71^{o} C, and a final extension step of 60 sec at 72^{o} C. The PCR amplification profile of RPB2 consisted of 5 min at 95 ^{o} C, followed by 35 cycles of 30 sec at 94 ^{o} C, 30 sec at 52 ^{o} C, 2 min at 72 ^{o} C, and 7 min at 72 ^{o} C. PCR product was purified using ExoSAP-IT treatment. Sequencing was done using the BigDye Terminator v3.1 Cycle Sequencing kit (Applied Biosystems, USA) in the ABI 3500 Genetic Analyzer. The primers used for PCR amplification were also used for sequencing. The sequencing PCR temperature profile of the ITS and LSU regions consisted of 2 minutes at 96^{o} C, followed by 30 cycles of 30 sec at 96^{o} C, 40 sec of 50^{o} C, 4 minutes of 60^{o} C. The sequencing temperature profile of RPB2 consisted of 5 min at 96 ^{o} C, 35 times cycle of 30 sec at 96 ^{o} C, 30 sec at 50 ^{o} C, 45 sec at 60 ^{o} C. DNA amplification and sequencing were done at the Rajiv Gandhi Center for Biotechnology (RGCB), Thiruvananthapuram, Kerala, AgriGenome Labs Private Limited, Kochi, Kerala, C-SIX Labs Private Limited, Palakkad, Kerala, and at the Barcode Bioscience Lab, Banglore. Quality of the obtained DNA sequences were

checked using Sequence Scanner Software v1 (Applied Biosystem). Alignment and editing of obtained DNA sequences were carried out using Geneious Pro v5.1 (Drummond *et al*. 2010) and BioEdit Sequence Alignment Editor. The newly generated sequences were deposited in the GenBank database (www.ncbi.nlm.nih.gov) and accession numbers were obtained. Sequence similarity assessments were conducted using a BLAST search in NCBI's GenBank nucleotide database (https://blast.ncbi.nlm.nih.gov/). BLAST search results with an identity of ≥90 %, with zero error value were considered for the phylogenetic analyses.

3.6. PHYLOGENETIC ANALYSES

Phylogenetic analysis of *Clavaria cystidiata* and related taxa

The newly generated sequences and ITS sequences retrieved from GenBank of 47 representative sequences in Clavariaceae (Table 4) were aligned using MEGA X64 (Kumar *et al.* 2018). Clavariaceae species with ITS sequences available in GenBank were included in the dataset. *Trechispora havencampii* Desjardin & B.A. Perry (Hydnodontaceae, Trechisporales) was chosen as the outgroup taxon following Birkebak *et al.* (2013). Phylogenetic analyses were conducted using Maximum Likelihood (ML) method and Bayesian analysis. Maximum Likelihood (ML) analysis was conducted with MEGA X64 using Tamura-Nei model (Tamura & Nei 1993). Initial trees for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pair wise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. The tree with the highest log likelihood value (–16331.38) was selected. The tree was drawn to scale, with branch lengths measured in the number of substitutions per site. Bayesian analysis was conducted with MrBayes 3.2 (Ronquist *et al.* 2012). Bayesian phylogenetic inference was done with a T92+G model with discrete gamma distributed substitution rates for the sequence dataset. The best-fit likelihood model of evolution was estimated in MEGA. Multiple independent analyses were run from random starting trees for four million generations, with trees saved every 100 generations, using four chains and a burnin fraction of 0.25. The aligned sequence data matrix was deposited in TreeBase

(Submission ID: 26259). In the phylogenetic tree, bootstrap values above 50% are shown (Figure 37).

TABLE 4. List of the species in the family Clavariaceae, GenBank accession numbers, voucher numbers and locality used in this study. Sequence accession generated during this study are highlighted in bold.

Taxon	GenBank numbers	Voucher numbers	Locatlity
Clavaria acuta	AY228353	1F14294	-
Clavaria amoenoides	MF972891	AMB 018217	Italy
Clavaria argillacea	KC759438.1	K(M)126733	England
Clavaria asterospora	KC759440	BIO-Fungi 12390	Spain
Clavaria atrofuscata	HQ606080	BRACR13264	Norway
Clavaria atropuncta	HQ6621654	G4-2010	Ireland
Clavaria calabrica	MF972889	ZT Myc 58697	Italy
Clavaria californica	HQ179660	TENN:026785	USA
Clavaria citrinorubra	HQ179661.1	TENN:040464	Australia
Clavaria crosslandii	KC75944.1	BIO-Fungi 12762	Spain
Clavaria cystidiata	**MK751792**	**CAL 1769**	**India**
Clavaria falcata	KC759445.1	AB0532 (BRA)	Wales
Clavaria flavipes	KC759451.1	OJ362006 (BRA)	Austria
Clavaria flavostellifera	KC759462	BRACR16695	Spain
Clavaria fumosa	MK427065	zp-2225	China
Clavaria fuscata	KP257128	TENN065665	USA
Clavaria greletti	MF503244	ERRO 2014102	Spain
Clavaria griseobrunnea	NR158336	12566	Spain
Clavaria incarnata	KC759452.1	BIO-Fungi 1256	Spain
Camarophyllopsis schulzeri	GU187556.1	GG091005	UnitedKingdom
Clavaria redoleoalii	MF664111.1	PDD:105311	NewZealand
Clavaria rosea	MK909560	TUR 201239	Finland
Clavaria rubicundula	MK578690	6603126	USA
Clavaria sphagnicola	KC759456.1	BRNM747282	Czech Republic
Clavaria tenuipes	KC759457	K(M)146565	United Kingdom
Clavaria tyrrhenica	MF972890	ZT Myc 58698	Italy
Clavaria zollingeri	MH016820	FLAS-F-60642	USA
Clavicorona taxophila	AF033344.1	71850	-
Clavulinopsis amoena	MK427063.1	ZP-2400	China
Clavulinopsis cf. helvola	KT275650.1	SE-2015	USA

Taxon	GenBank numbers	Voucher numbers	Locatlity
Clavulinopsis fusiformis	KM248914.1	2718	-
Clavulinopsis laeticolor	EU118618.1	EL 8/00 (GB	Finland
Clavulinopsis miyabeana	MK427059.1	ZP-2118	China
Clavulinopsis sulcata	MK427060.1	ZP-2119	China
Camarophyllopsis atrovelutina	KU882900.1	TL2014-682591	Denmark
Camarophyllopsis phaeophylla	MK139805.1	ERRO 2013112901	France
Camarophyllopsis rugulosa	NR_119896.1	TENN 023664	USA
Camarophyllopsis atropuncta	HQ662165.1	4G4-2010	Ireland
Camarophyllopsis schulzeri	GU187556.1	GG091005	United Kingdom
Hyphodontiella multiseptata	EU118634.1	Ryberg 021022 (GB)	Sweden
Mucronella sp.	HQ533013.1	PDD: 95742	New Zealand
Mucronella sp.	MH409972.1	strain 1214	New Zealand
Mucronella bresadolae	DQ384591.1	F15204	-
Ramariopsis flavescens	NR_119913.1	TENN 027570	USA
Ramariopsis kunzei	MK616542.1	AMB n. 17485	Italy
Ramariopsis crocea	MK607557.1	302989	USA
Ramariopsis pulchella	KX812470.1	MCCNNU00981	China
Trechispora heavencampii	NR151488.1	SFSU DED8300	-

Phylogenetic analysis of *Gomphus zamorinorum* and related taxa

The newly generated sequences and those taken from GenBank (Table 5) were aligned using MEGA X64 (Kumar *et al.* 2018). ITS sequences of Gomphaceae species available in GenBank were included in the dataset. The dataset included 50 taxa. *Calocera cornea* (Batsch) Fr. was selected as the outgroup taxon for the dataset. Maximum likelihood (ML) analysis was conducted with MEGA X64 using Tamura-Nei model (Tamura & Nei 1993), with 1000 bootstrap replicates. The aligned sequence data matrix was deposited in TreeBase (Submission ID: 29738). In the phylogenetic tree, BS values above 50 % alone are shown (Figure 8).

TABLE 5. List of the selected species in the family Gomphaceae, GenBank accession numbers of sequences (ITS), voucher numbers and locality used in this study. Sequence accessions generated during this study are highlighted in bold.

Taxon	GenBank numbers	Voucher numbers	Locatlity
Gomphus clavatus	AJ292292	MA-Fungi 48085	Spain
Gomphus zamorinorum	**ON732852**	**ZGCKP203A**	**India**
Gomphus zamorinorum	**ON732853**	**ZGCKP203B**	**India**
Phaeoclavulina pseudozippelii	NR164260	BBH43575	Thailand
Phaeoclavulina pseudozippelii	MG214660	BBH53576	Thailand
Phaeoclavulina abietina	OL455055	HBAU15347	-
Phaeoclavulin aabietina	MZ157226	HBAU15346	-
Phaeoclavulina macrospora	MT452510	AMB18614	Italy
Phaeoclavulina ochracea	MT055924	AMB18542	Italy
Phaeoclavulina cyanocephala	KT339249	TH9064	Guyana
Phaeoclavulina cokeri	MH322666	MA FUNGI 79873	Spain
Phaeoclavulina clavarioides	LR723646	PRM:945440	Czech Republic
Phaeoclavulina subdecurrens	MT055930	AMB 18548	Italy
Phaeoclavulina arcosuensis	MT055916	AMB 18532	Italy
Ramaricium polyporoideum	MH558292	MO313260	USA
Ramaricium polyporoideum	MF992160	ECV4163	USA
Ramaria stricta	DQ367910	OUC67191	-
Ramaria fumigata	KX814451	NIFoS2370	South Korea
Ramaria rubiginosa	MK169347	WTU-F-063044	USA
Ramaria celerivirescens	MK169343	WTU-F-043209	USA
Ramaria magnipes	MK169351	WTU-F-063057	USA
Ramaria pallidissima	NG_075339	ZT Myc 55616	Spain
Ramaria botrytis	KJ184344	DARD-112	India
Ramaria rubribrunnescens	MK169352	WTU-F-063038	USA
Ramaria thindii	NR_171845	CAL 1786	India

Taxon	GenBank numbers	Voucher numbers	Locatlity
Ramaria verlotensis	KX574480	WTU-F-063047	USA
Ramaria abetonensis	NR_155721	MCVE28638	-
Ramaria luteovernalis	NR_155720	MCVE28637	-
Ramaria admiratia	NR_137862	TENN 69114	USA
Ramaria clavodistalis	NR_137861	TENN 69095	USA
Calocera cornea	AB841070	H No267ss	Japan

Phylogenetic analysis of *Clavaria viriditincta* and related taxa

The newly generated sequences were subjected to BLAST search in the GenBank nucleotide database for finding taxa with close sequence similarity. A data matrix was constructed by combining the newly generated sequences and ITS and LSU sequences retrieved from GenBank. The dataset included 35 representative sequences of the family Clavariaceae (Table 6). *Trechispora havencampii* Desjardin & B.A. Perry (Hydnodontaceae, Trechisporales) was chosen as the outgroup taxon following Birkebak *et al*. (2013). DNA sequences of the ITS-LSU combined dataset were aligned automatically with MUSCLE in MEGA (Kumar *et al*. 2018) and then manually edited using the same programme. Phylogenetic analysis was conducted using Maximum Likelihood (ML) method using Tamura-Nei model (Tamura & Nei 1993) in MEGA. Initial tree for the heuristic search were obtained automatically by applying Neighbour-Join and BioNJ algorithms to a matrix of pair wise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. The tree with the highest log likelihood value (-11463.39) was selected. The tree was drawn to scale, with branch lengths measured in the number of substitutions per site (Figure 50).

TABLE 6. List of the Clavariaceae species, GenBank accession numbers of sequences (ITS and LSU), voucher numbers and locality used in this study. Sequence accessions generated during this study are highlighted in bold.

Taxon	GenBank numbers		Voucher numbers	Locality
	ITS	LSU		
Clavaria acuta	AY228353	GU299506	F14294	-
Clavaria argillacea	KC759438	JQ415931	K(M)126733	England
Clavaria asterospora	KC759440	-	BIO-Fungi 12390	Spain
Clavaria calabrica	NR166562	MF972885	ZTMYC58697	Italy
Clavaria citrinorubra	HQ179661	HQ877686	TENN:040464	Australia
Clavaria crosslandii	KC75944	-	BIO-Fungi 12762	Spain
Clavaria cystidiata	MK751792	-	CAL 1769	India
Clavaria falcata	KC759445	-	AB0532	Wales
Clavaria flavipes	KC759451	GU299507	OJ362006	Austria
Clavaria incarnata	KC759452	KP257245	BIO-Fungi 12560	Spain
Clavaria macounii	KP257131	KP257202	PK1536	Canada
Clavaria viriditincta	**OP627565**	**OP895708**	**ZGCKP247**	**India**
Clavaria redoleoalii	MF664111	DQ284906	PDD105311	NewZealand
Clavaria sphagnicola	KC759456	KC759471	B RNM 747282	Czech Republic
Clavicorona taxophila	AF033344	KP257216	71850	-
Clavulinopsis cf. *helvola*	KT275650	KT275650	SE-2015	USA
Clavulinopsis fusiformis	KM248914	EF535273	2718	-
Clavulinopsis laeticolor	EU118618	-	EL 8/00	Finland
Clavulinopsis miyabeana	MK427059	-	ZP.2118	China
Clavulinopsis sulcata	MK427060	DQ284904	ZP-2119	China
Camarophyllopsis atrovelutina	KU882900	KP257175	TL2014-682591	Denmark
Camarophyllopsis phaeophylla	MK139805	-	1ERRO 2013112901	France
Camarophyllopsis rugulosa	NR_119896	-	TENN 023664	USA
Camarophyllopsis atropuncta	HQ662165	KP257217	4G4-2010	Ireland
Camarophyllopsis schulzeri	GU187556	-	GG091005	Wales
Hyphodontiella multiseptata	EU118634	-	Ryberg 021022 (GB)	Sweden
Mucronella sp.	HQ533013	-	PDD95742	NewZealand
Mucronella sp.	MH409972	-	strain 1214	NewZealand
Mucronella sp.	MZ750956	-	iNAT82769617	USA
Mucronella bresadolae	DQ384591.1	-	F15204	-

Taxon	GenBank numbers		Voucher numbers	Locality
	ITS	LSU		
Ramariopsis flavescens	NR_119913	-	TENN 027570	USA
Ramariopsis kunzei	MK616542	MZ042257	AMB n. 17485	Italy
Ramariopsis crocea	MK607557	GU299492	302989	USA
Ramariopsis pulchella	KX812470	KY819095	MCCNNU00981	China
Trechispora havencampii	NR151488	-	SFSU DED8300	-

Phylogenetic analysis of *Ramariopsis subtilis* and related taxa

The newly generated sequence and ITS sequences retrieved from GenBank (following Krishnapriya & Kumar 2021) (Table 7) were aligned using MEGA X64 (Kumar *et al.* 2018). *Trechispora havencampii* Desjardin & B.A. Perry (Hydnodontaceae, Trechisporales) was chosen as the outgroup taxon following Birkebak *et al.* (2013). Phylogenetic analysis was conducted using Maximum Likelihood (ML) method. ML analysis was conducted with MEGA X64 using Tamura-Nei model (Tamura & Nei 1993). Initial trees for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pair wise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. The tree with the highest log likelihood value (-13987.27) was selected (Figure 73).

TABLE 7. List of the Clavariaceae species, GenBank accession numbers of sequences (ITS), voucher numbers and locality used in this study. Sequence accession generated during this study are highlighted in bold.

Taxon	GenBank numbers ITS	Voucher numbers	Locatlity
Clavaria acuta	AY228353	F14294	-
Clavaria argillacea	KC759438	K(M)126733	England
Clavaria asterospora	KC759440	BIO-Fungi 12390	Spain
Clavaria citrinorubra	HQ179661	TENN:040464	Australia
Clavaria crosslandii	KC75944	BIO-Fungi 12762	Spain
Clavaria cystidiata	MK751792	CAL 1769	India
Clavaria falcata	KC759445	AB0532	Wales
Clavaria flavipes	KC759451	OJ362006	Austria
Clavaria macounii	KP257131	PK1536	Canada

Taxon	GenBank numbers ITS	Voucher numbers	Locatlity
Clavaria viriditincta	OP627565	ZGCKP247	India
Clavaria redoleoalii	MF664111	PDD105311	NewZealand
Clavaria sphagnicola	KC759456	B RNM 747282	Czech Republic
Clavicorona taxophila	AF033344	71850	-
Clavulinopsis amoena	MK427063	ZP-2400	China
Clavulinopsis appalachiensis	OP749256	271567	USA
Clavulinopsis aurantiocinnabarina	ON416905	NEMF2018	USA
Clavulinopsis cf. *helvola*	KT275650	SE-2015	USA
Clavulinopsis fusiformis	KM248914	2718	-
Clavulinopsis laeticolor	EU118618	EL 8/00	Finland
Clavulinopsis miyabeana	MK427059	ZP.2118	China
Clavulinopsissulcata	MK427060	ZP-2119	China
Camarophyllopsis atrovelutina	KU882900	TL2014-682591	Denmark
Camarophyllopsis phaeophylla	MK139805	1ERRO 2013112901	France
Camarophyllopsis rugulosa	NR_119896	TENN 023664	USA
Camarophyllopsis atropuncta	HQ662165	4G4-2010	Ireland
Camarophyllopsis schulzeri	GU187556	GG091005	Wales
Hyphodontiella multiseptata	EU118634	Ryberg 021022 (GB)	Sweden
Mucronella sp.	HQ533013	PDD95742	NewZealand
Mucronella sp.	MH409972	strain 1214	NewZealand
Mucronella sp.	MZ750956	iNAT82769617	USA
Mucronella bresadolae	DQ384591.1	F15204	-
Ramariopsis flavescens	NR_119913	TENN 027570	USA
Ramariopsi gilibertoi	NR173169	AMB 17688	Italy
Ramariopsis kunzei	MK616542	AMB n. 17485	Italy
Ramariopsis mintula	OM985843	MICH 340329	USA
Ramariopsis crocea	MK607557	302989	USA
Ramariopsis pulchella	KX812470	MCCNNU00981	China
Ramariopsis subtilis	**OQ030272**	**ZGCKP136**	**India**
Ramariopsis subtilis	MT05595	AMB18571	Italy
Trechispora havencampii	NR151488	SFSU DED8300	-

Phylogenetic analysis of the order Trechisporales

The data set included a total of 94 taxa (Table 8). Eight newly generated ITS sequences and those sequences retrieved from GenBank of 70 representative sequences in the order Trechisporales (following Liu *et al.* 2022), 11 representative sequences in the genus *Clavulina* (Hydnaceae, Cantherellales) and three representative sequences of the newly segregrated order Sistotrematales, were aligned using MEGA X64 (Kumar *et al.* 2018). *Neofavolus alveolaris* (DC.) Sotome & T. Hatt. and *Cerioporus squamosus* (Huds.) Quèl. (Polyporaceae, Polyporales) were chosen as the outgroup taxon, following Liu *et al.* (2022). DNA sequences of the ITS dataset were aligned automatically with MUSCLE in MEGA (Kumar *et al*. 2018) and then manually edited using the same programme. Phylogenetic analysis was conducted using Maximum Likelihood (ML) method with MEGA X64 using Tamura-Nei model (Tamura & Nei 1993). Initial trees for the heuristic search were obtained automatically by applying Neighbor-Join and BioNJ algorithms to a matrix of pair wise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. The tree with the highest log likelihood value (-33395.11) was selected. The tree was drawn to scale, with branch lengths measured in the number of substitutions per site. In the phylogenetic tree, BS values above 50 % alone are shown (FIGURE 28).

TABLE 8: List of the Trechisporales taxa, GenBank accession numbers of sequences (ITS), voucher numbers and locality used in this study. Sequence accessions generated during this study are highlighted in bold.

Taxon	GenBank numbers	Voucher numbers	Locatlity
Allotrechispora daweishanensis	MW302337	CLZhao17860	China
Allotrechispora xantha	MW302339	CLZhao2632	China
Brevicellicium atlanticum	HE963773	LISU178566	Portugal
Brevicellicium xanthum	MW302340	CLZhao17781	China
Clavulina cerebriformis	J168690	MCA4022	Guyana
Clavulina cerebriformis	NR121504	BRGMCA4022	Guyana
Clavulina cinereoglebosa	NR119975	BRGTH8561	Guyana
Clavulina rosiramea	NR120086	BRGTH8954	Guyana
Clavulina craterelloides	NR12114	BRGTH8324	Guyana

Taxon	GenBank numbers	Voucher numbers	Locatlity
Clavulina caespitose	NR119560	BRGTH8709	Guyana
Clavulina guyanensis	NR120085	BRGTH9245	Mexico
Clavulina parvispora	NR166245	FCME27650	Guyana
Clavulina monodiminutiva	NR119559	BRGTH8738	Guyana
Clavulina pakaraimensis	NR121533	BRGTH9194	Mexico
Clavulina tepurumenga	NR119925	NY1194099	China
Dextrinocystis calamicola	MK204533	He5693	China
Dextrinocystis calamicola	MK204534	He5701	China
Fibrodontia alba	NR153983	TNMF24944	China
Fibrodontia alba	MK204599	He4761	China
Fibrodontia austrosinensis	MT802109	He3453	China
Fibrodontia brevidens	MK204528	He3559	China
Fibrodontia subalba	MT802106	Dai15931	Portugal
Luellia cystidiata	MW371211	JHP-09455	Norway
Luellia recondita	UDB038222	O-F-253622	Czeh Republic
Porpomyces mucidus	KT157833	Dai12692	China
Porpomyces submucidus	KT152143	CUI5183	China
Subulicystidium acerosum	MK204539	He3804	USA
Subulicystidium brachysporum	MK204533	He2207	Costa Rica
Subulicystidium boidinii	MH041537	KHA12830	Puerto Rico
Subulicystidium fusisporum	MH041535	KHA10360	Costa Rica
Subulicystidium grandisporum	MH041547	506781	Reunion
Subulicystidium harpagum	MH041532	L1726a	Brazil
Subulicystidium meridense	MH041538	Hjm16400	Reunion
Subulicystidium nikau	MH041513	L1296	Reunion
Subulicystidium parvisporum	MH041529	L0140	Jamaica
Subulicystidium robustius	MH041514	KHL10813	Slovenia
Sertulicium lateclavigerum	MW049161	Spirin13457	China
Sertulicium guttuliferum	MK204540	He3338	China
Sistotremastrum aculeatum	MN991176	Miettinen 10380	Brazil
Scytinopogon scaber	MK458773	FLOR56189	Brazil
Scytinopogon sp.	MK458769	FLOR56315	India
Scytinopogon sp.	KT04576	BAB5120	India
Scytinopogon sp.	MZ518207	MYB-2021a	Australia
Scytinopogon sp.	KP012947	MEL2382992	Brazil
Scytinopogon robustus	MK458770	FIOR56179	Sweden
Trechispora araneosa	AF347084	KHL8570	-
Trechispora alnicola	DQ411529	AFTOL-ID665	-

Taxon	GenBank numbers	Voucher numbers	Locatlity
Trechispora angulispora	**OP6275666**	**ZGCKP255**	**India**
Trechispora caulocystidiata	MK458772	FLOR56314	Brazil
Trechispora cf. cohaerens	KP814538	UC2022832	USA
Trechispora confinis	AF347081	KHL11064	Sweden
Trechispora copiosa	MN701014	AMO423	Brazil
Trechispora corneri	**OP881892**	**ZGCKP237**	**India**
Trechispora chartacea	MK458775	FLOR56185	Brazil
Trechispora cystidiata	**OP627562**	**ZGCKP152**	**India**
Trechispora cystidiata	**OP627563**	**ZGCKP212**	**India**
Trechispora dealbata	MK458776	FLOR56182	Brazil
Trechispora dealbata	**OP948880**	**ZGCKP137**	**India**
Trechispora dentata	OK298491	Dai22565	China
Trechispora dimitiella	OK298493	Dai21181	China
Trechispora echinospora	JX392845	E11/37-03	Equatorial Guinea
Trechispora echinospora	JX392853	E11/37-12	Equatorial Guinea
Trechispora fissurata	MW544027	CLZhao4571	China
Trechispora foetida	MK458769	FLOR 56315	Brazil
Trechispora foetida	**OP881893**	**ZGCKP161**	**India**
Trechispora fragilis	OK298494	Dai 20535	China
Trechispora fimbriata	EU909231	CLZhao4154	Germany
Trechispora gelatinosa	MN701021	AMO1139	Brazil
Trechispora gelatinosa	MN701020	AMO824	Brazil
Trechispora hymenocystis	MT816397	KHA16444	Norway
Trechispora hondurensis	MT571523	HONDURAS19-	Honduras
Trechispora havencampii	NR154418	F016a	Africa
Trechispora havencampii	**OP881891**	**ZGCKP160**	**India**
Trechispora invisitata	KP814182	UC2022935	USA
Trechispora invisitata	KP814425	UOC2023088	USA
Trechispora incisa	AF347085	EH24/98	-
Trechispora incisa	KU747095	GB-0090648	Sweden
Trechispora laevispora	OK298495	Dai21655	China
Trechispora nivea	JX392837	MA-FUNGI76253	-
Trechispora papillosa	MN701022	AMO713	Brazil
Trechispora papillosa	MN701023	AMO795	Brazil
Trechispora pallescens	MK458774	FLOR56188	Brazil
Trechispora robusta	MK458770	FLOR56179	Brazil
Trechispora robusta	**OP881894**	**ZGCKP160**	**India**
Trechispora subsphaerospora	AF347080	UC2022935	Sweden
Trechispora stevensonii	JX392843	UC2023088	-

Taxon	GenBank numbers	Voucher numbers	Locatlity
Trechispora stevensonii	JX392841	EH24/98	-
Trechispora torrendii	MK515148	GB0090648	Brazil
Trechispora termitophila	MN701024	Dai21655	Brazil
Neofavolus alveolaris	Dai11290	MA-Fungi76253	China
Polyporus squamosus	KU189778	AMO713	China

4. RESULTS

4.1. TAXONOMIC KEYS TO THE CLAVARIOID FUNGI OF KERALA

Key to the orders

1a. Basidiomata dull white to cream; basidia sulcately divided at the apex..... ..... **Tremellodendropsidales**

1b. Basidiomata variously coloured; basidia simple, not sulcately divided at the apex 2

2a. Gloeocystidia and dichophyses present; basidiospores amyloid ..... **Russulales**

2b. Gloeocystidia present or not; dichophyses absent; basidiospores inamyloid 3

3a. Positive reaction to Fe_3Cl, turning green ..... **Gomphales**

3b. No positive reaction to Fe_3Cl..... 4

4a. Hymenophore smooth; basidiospores angular and ornamented; hyphae with ampullate septations..... **Trechisporales**

4b. Hymenophore smooth to wrinkled; basidiospores not angular, smooth or ornamented; hyphae without ampullate septations 5

5a. Basidiomata white to grey; basidiospores globose and smooth; basidia pseudoseptate or aseptate; hyphae monomitic (always with these combination of characters)..... **Cantharellales**

5b. Basidiomata variously coloured; basidiospores subglobose, globose, ellipsoid, fusiform, smooth to ornamented; basidia aseptate; hyphae monomitic or dimitic ..... **Agaricales**

Order Tremellodendropsidales

Basidiomata subcoriaceus to tough, erect, with terete to flattened branches, dull white to cream in colour, basidiospores smooth, basidia with sulcate divisions at the apex, monomitic hyphal system with clamp-connections. The order includes a single family Tremellodendropsidaceae and a single genus *Tremellodendropsis.*

Family Tremellodendropsidaceae

Basidiomata light-coloured with erect, clavarioid branching, basidiospores smooth, false septate basidia with clamp-connection, hyphae monomitic with clamp-connections.

Key to the taxa of *Tremellodendropsis*

1a. Basidiomata less branched, apex acerose, brownish on bruising; basidiospores 8–15 × 6–7 µm; with basidial clamp-connection .....*T. pusio*

1a. Basidiomata highly branched, apex not acerose, no colour changes on bruising; without basidial clamp-connection 2

2a. Basidiospores fusiform, 11–17 × 6–8 µm; sterigmata two ..... *T. tuberosa*

2b. Basidiospores globose, 9–10 × 8–9 µm; sterigmata four ..... *T. flagelliformis*

Order Russulales

Basidiomata resupinate to clavarioid, pileate, or gasteroid, hymenophore smooth to poroid, hydnoid, and lamellate. Basidiospores amyloid, gloeocystidia present. All the members with clavarioid basidiomata of this order are kept in the genus *Lachnocladium* of the family Peniophoraceae.

Family Peniophoraceae

The family is characterized by the presence of papillate skeletal hyphae, dicophyses, skeletodendrohyphidia, lamprocystidia, and gloeocystidia.

Key to the taxa of *Lachnocladium*

1a. Basidiomata brownish yellow, with whitish tips; basidiospores 3–4 × 3–4 µm; globose to subglobose.....*L. flavidum*

1b. Basidiomata brownish, with bright yellow tips; basidiospores 3–4 × 2.5–3 µm; lacrymoid .....*L. fulvum*

Order Gomphales

Basidiomata ramarioid, clavarioid to cantharelloid-gomphoid, resupinate, or odontoid. Basidiomata of some may be sequestrate. Basidiospores verrucose to echinulate, cyanophilic in cotton blue. Basidia chiastic, hyphae with constrictions. Hymenia showing positive reaction with ferric chloride.

Family Gomphaceae

Basidiomata resupinate-odontoid, clavarioid, hydnoid, or agaricoid. Basidiospores are ellipsoid, with rugose walls, cyanophilic in cotton blue, ochraceous to hyaline. Treatment with ferric chloride turns basidiomata green.

Key to the genera of Gomphaceae

1a. Basidiomata branched, clavarioid, hymenophore smooth, cystidia absent 2

1b.Basidiomata meristamoid to pileate, hymenophore wrinkled or folded; basidiospores 6–7 × 4–5 µm; cystidia present⋯⋯⋯⋯ *Gomphus zamorinorum*

2a.Basidiomata branched; generative hyphae inflated or not, gleopherous hyphae absent .....*Ramaria*

2b.Basidiomata pileate to branched; generative hyphae not inflated; gleopherous hyphae present⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯⋯ *Phaeoclavulina*

Key to the taxa of *Ramaria*

1a. Basidiomata cream to yellowish brown.....2

1b. Basidiomata white, becoming pinkish on bruising and aging; basidiospores 4–5 × 3–4 µm..... *R. pusilla*

2a. Basidiomata darker towards the branch apex 3

2b. Basidiomata paler towards the branch apex 4

3a. Basidia bi-sterigmate; basidiospores obovoid to ellipsoid, 10–15 × 5–6 µm..... ..... *R. grandis*

3b. Basidia tetra-sterigmate; basidiospores fusiform.....5

4a. Basidium with basal clamp-connection 6

4b. Basidium without basal clamp-connection 7

5a. Basidium with basal clamp-connection; hyphae without clamp-connections; basidiospores 10–14 × 4–5 µm .....*R. divaricata*

5b. Basidium without basal clamp-connection; hyphae with clamp-connections..... 8

6a. Basidiospores 7–10 × 5–7 µm; hyphae inflated.....*R. gelatinosa*

6b. Basidiospores 9–11 × 4–5 µm; hyphae not inflated ..... *R. suecica*

7a. Basidiospores fusiform, echinulate, 10–15 × 5–6 µm ..... *R. subaurantiaca*

7b. Baidiospores ellipsoid, veruccose.....9

8a. Basidiospores fusiform, 10–15 × 5–6 µm; basidia 53–80 × 7–10 µm; hyphae not inflated ..... *R. fragillima*

8b. Basidiospores ellipsoid, 6–9 × 4–5 µm; basidia 27–32 × 6–7 µm; hyphae inflated ..... *R. subsigmoidea*

9a. Basidiospores 9–10 × 4–5 µm; hyphae not inflated ..... *R. stricta*

9b. Basidiospores 6–8 × 4–5 µm; hyphae inflated ..... *R. gracilis*

Key to the taxa of *Phaeoclavulina*

1a. Basidiomata brownish, bluish towards the apex; basidiospores 13–16 × 8–10 µm; bisterigmate basidia ..... *P. cyanocephala*

1b. Basidiomata brownish, yellowish towards the apex; basidiospores 10–15 × 6–8 µm; tetrasterigmate basidia..... *P. cokeri*

Order Trechisporales

Basidiomata with smooth hymenophore, non-lamellate. Basidiospores angular, veruccose, basidia small. Hyphae monomitic, with ampullate septations, and clamp-connections. Only a single family, Hydnodontaceae has been recognized with the same characteristics of the order.

Key to the taxa of Hydnodontaceae

1a. Basidiomata purple to dark brown.....2

1b. Basidiomata white to greyish.....3

2a. Basidiomata brownish to purple; branches pruinose 4

2b. Basidiomata white with purple tinge and dark brown branches; basidiospores 5–6 × 4–5 µm; branches glabrous..... *T. foetida*

3a. Basidiospores 6–7 × 4–5 µm 5

3b. Basidiospores 4–5 × 3–4 µm .....*T. dealbata*

4a. Basidia tetra- sterigmate 6

4b. Basidia bi-sterigmate, basidiospores 6–7 × 4–6 µm..... *T. havencampii*

5a. Basidiomata greyish white; basidiospores 6–7 × 4–5 µm; hyphae not inflated .... *T. robusta*

5b. Basidiomata white; basidiospores 5–7 × 4–5 µm; hyphae inflated *T. angulispora*

6a. Basidiomata tomentose at base; basidiospores 6–7 × 4–5 µm; hyphae inflated; cystidia present ..... *T. cystidiata*

6b. Basidiomata glabrous; basidiospores 4–7 × 4–5 µm; hyphae not inflated; cystidia absent ..... *T. corneri*

Order Cantherellales

Basidiomata clavarioid. Hymenophore smooth. Basidiospores smooth, globose. Basidia with two to four sterigmata, aseptate or pseudoseptate. Hyphae monomitic, not inflated.

Key to the families of Cantherellales

1a. Basidiomata branched; basidia aseptate, tetra-sterigmate; hymenium fertile towards the apex, clamp-connections absent ..... Aphelariaceae (*A. dendroides*)

1b. Basidiomata simple to branched; basidia aseptate or pseudoseptate, bi-sterigmate; hymenium amphigenous, clamp-connections present or absent ⋯⋯⋯ Hydnaceae ……..… (*Clavulina*)

Family Hydnaceae

Basidiomata clavarioid, cream, white, grey, ochraceous to pale purplish. Basidia septate to aseptate, bisterigmate, hyphal clamp-connections present or absent.

Key to the taxa of *Clavulina*

1a. Basidiomata branched 2

1b. Basidiomata simple or branching once 3

2a. Basidium with basal clamp-connection 4

2b. Basidium without basal clamp-connection; basidiospores 9–11 × 6–10 µm .... *C. cristata*

3a. Basidia pseudoseptate 5

3b. Basidia not pseudoseptate 6

4a. Basidiomata strigose-hispid; basidiospores 8–9 × 7–8 µm; hyphal clamp-connections absent ..... *C. ornatipes*

4b. Basidiomata smooth; basidiospores 9–10 × 7–8 µm; hyphal clamp-connections present ..... *C. cinerea*

5a. Basidiomata branching once, greyish brown; basidial clamp-connection absent; basidiospores 8–12 × 7–9 µm ..... *C. livida*

5b. Basidiomata simple, yellowish brown; basidial clamp-connection present; basidiospores 9–10 × 8–9 µm ..... *C. floridana*

6a. Basidiomata larger, rugose; basidiospores 8–12 × 8–10 µm ..... *C. rugosa*

6b. Basidiomata small, not rugose; basidiospores 8–9 × 6–8 µm ..... *C. humilis*

Order Agaricales

Basidiomata fleshy, simple to branched. Basidia aseptate, basidiospores smooth or ornamented. Hyphae typically monomitic, rarely dimitic, with or without clamp-connections.

Key to the families of Agaricales

1a. Basidiomata terrestrial, variously coloured; basidiospores smooth to ornamented; hyphae monomitic ····· Clavariaceae

1b. Basidiomata epiphytic, dull white to ochraceous; basidiospores smooth; hyphae monomitic to dimitic ····· 2

2a. Basidiomata cylindrical throughout and not differentiated into head and stipe, with filiform branches; hyphae dimitic and uninflated ..... Pterulaceae

2b. Basidiomata with distinct, without filiform branches; hyphae monomitic and inflated ..... Typhulaceae

Family Clavariaceae

Basidiomata simple to branched, white, yellow, orange, pink, violet, brown or black. Basidiospores smooth to ornamented, thin- to thick-walled. Hyphae monomitic, with or without clamp-connections.

Key to the genera of Clavariaceae

1a. Basidiospores smooth; loop-like clamp-connection at the base of basidium; hyphae without clamp-connections ····· *Clavaria*

1b. Basidiospores smooth to echinulate; normal clamp-connection at the base of basidia; hyphae with clamp-connections ····· 2

2a. Basidiomata simple or branched; basidiospores generally smooth (except *C. helvola*) ····· *Clavulinopsis*

2b. Basidiomata branched; basidiospores regularly echinulate ..... *Ramariopsis*

Key to the taxa of *Clavaria*

1a. Basidiomata simple 2

1b. Basidiomata branched.....3

2a. Basidiomata with garlic odour; basidiospores 7–10 × 5–8 µm; cystidia present ....*C. cystidiata*

2b. Basidiomata without garlic odour; cystidia absent 4

3a. Basidiomata creamy white with pale purplish tinge; basidiospores 5–6 × 4–5 µm ..... *C. sinensis*

3b. Basidiomata violet; basidiospores 5–6 × 4–5 µm.....*C. zollingeri*

4a. Basidiomata white, yellowish, pink or green.....5

4b. Basidiomata grey or black 6

5a. Basidia with basal clamp-connection.....7

5b. Basidia without basal clamp-connection 8

6a. Baisiomata cylindrical with round tips; basidiospores 7–10 × 4–5 µm, ellipsoid... ..... *C. xylarioides*

6b. Basidiomata fusiform with acute tips; basidiospores 8–10 × 7–8 µm, globose ....*C. greletii*

7a. Basidiomata cream, with yellowish apex; basidiospores 7–10 × 6–8 µm .....…….*C. gibbsiae*

7b. Basidiomata orange; basidiospores 6–8 × 7–8 µm.....*C. luteostirpata*

8a. Basidiomata reddish pink; basidiospores 6–8 × 3–4 µm; bi-sterigmate.... *C. rosea*

8b. Basidiomata white to yellow or green; tetra-sterigmate 9

9a. Basidiospores 6–8 × 4–5 µm .....*C. vermicularis*

9b. Basidiospores 4–6 × 4–5 µm 10

10a. Basidiomata small, 25–40 mm long, simple and solitary 11

10b. Basidiomata larger, 70–110 mm long, in caespitose clusters.....12

11a. Basidiospores echinulate, 6–8 × 5–7 µm. .....*C. echinonivosa*

11b. Basidiospores smooth, 5–7 × 4–5 µm 13

12a. Basidiomata white to creamy white 14

12b. Basidiomata dark green; basidiospores 6–7 × 4–5 µm, ellipsoid..... ..... *C. viriditincta*

13a. Basidiomata white; basidiospores 5–6 × 4–5 µm, globose..... *C. citriceps*

13b. Basidiomata greenish yellow; basidiospores 5–6 × 3–4 µm, ellipsoid……. ..... *C. macounii*

14b. Basidiomata white; basidiospores 4–5 × 3–4 µm.....*C. fragilis*

14b. Basidiomata cream; basidiospores 5–7 × 4–5 µm.....*C. fumosa*

Key to the taxa of *Clavulinopsis*

1a. Basidiomata simple.....2

1b. Basidiomata branched.....3

2a. Basidiomata white to yellowish.....4

2b. Basidiomata bright orange.....5

3a. Basidia with basal clamp-connection.....6

3b. Basidia without basal clamp-connection 7

4a. Basidiomata cream.....8

4b. Basidiomata yellow 9

5a. Basidium without clamp-connection, bi-sterigmate; basidiospores 6–8 × 5–6 µm ..... *C. archeri*

5b. Basidium with clamp-connection, tetra-sterigmate 10

6a. Basidiomata whitish; basidiospores 5–6 × 4–5 µm ..... *C. semivestia*

6b. Basidiomata yellow, brown; basidiospores 6–7 × 4–5 µm.....11

7a. Basidiomata white, highly branched; basidiospores 5–6 × 4–5 µm, veruccose ....*C. subartica*

7b. Basidiomata yellow, less branched; basidiospores 4–5 × 3–4 µm, smooth .....*C. rufipes*

8a. Basidiomata larger; basidiospores 6–7 × 4–5 µm; basidia 35–46 × 5–6 µm; hyphae not inflated.....*C. arnicola*

8b. Basidiomata small; basidiospores4–7 × 4–5 µm; basidia 40–65 × 6–8 µm; hyphae inflated..... *C. brevipes*

9a. Basidiospores larger, 7–10 × 6–7 µm 12

9b. Basidiospores smaller, 5–7 × 4–6 µm 13

10a.Basidiospores 6–7 × 5–6 µm; basidia ruptured after spore discharge; hyphae not inflated .....*C. sulcata*

10b. Basidiospores 4–7 × 3–5 µm; basidia intact even after spore discharge; hyphae inflated .....*C. aurantiocinnabarina*

11a. Basidiomata yellow, with white apex; basidiospores 6–7 × 4–5 µm .....*C. corneculata*

11b. Basidiomata brownish yellow, apex concolourous with branches; basidiospores 6–7 × 5–6 µm ....*C. umbrinella*

12a. Basidiomata small.....14

12b. Basidiomata larger.....15

13a. Basidiospores echinulate, 6–7 × 5–6 µm..... *C. helvola*

13b. Basidiospores smooth.....16

14a. Basidiomata spathulate; basidiospores 7–10 × 5–6 µm ..... *C. spathuliformis*

14b. Basidiomata not spathulate; basidiospores 6–8 × 5–6 µm ..... *C. ochracea*

15a. Basidiomata yellowish to cream; basidiospores 6–8 × 5–7 µm *C. appalachiensis*

15b. Basidiomata lemon yellow; basidiospores 6–8 × 6–7 µm..... *C. fusiformis*

16a. Basidimata yellowish white, yellow towards the base; basidiospores 5–7 × 4–6 µm .....*C. spiralis*

16b. Basidiomata yellowish orange; basidiospores 5–7 × 4–6 µm ..... *C. amoena*

Key to the taxa of *Ramariopsis*

1a. Basidiomata white to ochraceous.....2

1b. Basidiomata brown with purplish tinge; basidiospores 4–5 × 3–4 µm ....*R. ramarioides*

2a. Basidiospores echinulate or verrucose. 3

2a. Basidiospores smooth, 4–5 × 3–4 µm .....*R. subtilis*

3a. Basidiomata ochraceous; basidiospores verrucose, 6–7 × 4–5 µm..... .....*R. clavuligera*

3b. Basidiomata white; basidiospores echinulate, 4–6 × 3–4 µm 4

4a. Basidiomata white, with yellowish apex, tomentose at the base; *basidiospores* 5–6 × 4–5 µm ..... *R. tenuiramosa*

4b. Basidiomata white, apex concolourous, not tomentose.....5

5a. Basidiospores 4–5 × 3–4 µm, verrucose; hyphae inflated.....*R. kunzei*

5b. Basidiospores 4–6 × 4–5 µm, echinulate; hyphae not inflated.....*R. robusta*

Family Pterulaceae

Basidiomata coralloid, deflexed. Hyphae dimitic (generative and skeletal hyphae), with or without clamp-connections, cystidia may or may not be present, basidiospores hyaline, smooth, inamyloid.

Key to the genera of Pterulaceae

1a. Basidiomata inverted or decurved; basidiospores fusiform; cystidia absent; hyphal clamp-connections absent .....*Pterulicicum*

1b. Basidiomata not so, basidiospores ellipsoid; cystidia present; hyphal clamp-connections present; basidiospores 6–7 × 4–5 µm..... *Pterula* (*P. verticillata*)

Key to the taxa of *Pterulicium*

1a. Basidiomata branched; basidiopsores 10–15 × 6–8 µm; basidia bi-sterigmate, with basal clamp-connection .....*P. secundirameum*

1b. Basidiomata simple; basidiospores 12–15 × 6–9 µm; basidia tetra-sterigmate, without basal clamp-connection .....*P. subsimplex*

Family Typhulaceae

Basidiomata small, distinct stipe with fertile head, hymenium smooth. Basidiospores smooth, ellipsoid. Hyphae monomitic, agglutinated, with clamp-connections, cystidia present or absent.

Key to the genera of Typhulaceae

1a. Basidiomata with distinct head and stalk; basidia with basal clamp-connection .....*Typhula*

1b. Basidiomata without distinct head and stalk, narrowly filiform; basidia witout basal clamp-connection ..... *Macrotyphula (M. phaccorhiza)*

Key to the taxa of *Typhula*

1a. Basidiopsores 8–10 × 6–8 µm, subglobose; cystidia absent..... *T. abietina*

1b. Basidiospores 4–6 × 4 µm, ellipsoid; cystidia present .....*T. sclerotioides*

4.2. TAXONOMIC DESCRIPTIONS AND MOLECULAR PHYLOGENY

Genus *Tremellodendropsis*

Basidiomata light-coloured with erect, clavarioid branching, basidiospores smooth, false septate basidia with clamp-connection, hyphae monomitic with clamp-connections.

Tremellodendropsis pusio (Berk.) D.A. Crawford, Trans. Roy. Soc. N.Z. 82(3): 620 (1954)

Basionym:
Clavaria pusio Berk., in Hooker 1855

Synonyms:
Aphelaria pusio (Berk.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 188 (1950)
Clavaria pusio Berk., in Hooker, Bot. Antarct. Voy. Erebus Terror 1839-1843, II, Fl. Nov.-Zeal.: *185* (1855)
*Pseudotremellodendron pusio (*Berk.) D.A. Reid, Kew Bull. [11]: 535 (1957) [1956]
Pseudotremellodendron pusio var. *papillatus* Maham., Kund. & M.S. Patil, Indian Phytopath. 55(4): 466 (2002)
Pterula pusio (Berk.) Bres., Hedwigia 56(4,5): 304 (1915)

FIGURE 2

Basidiomata 40 × 3 mm, with distinct stalk, dichotomously branched, fleshy, apex acute, acerose (up to 4 mm), smooth, terete in cross section, solid, ochre coloured, apex white, base off white, becoming brownish on bruising, without any distinct odour, turning brownish black on treatment with Fe_3Cl.

Basidiospores 8–15 × 6–7 µm (Q=1.33–2 µm, Q_m=1.76 µm), ellipsoid to fusiform, smooth, uniguttulate, thin-walled, hyaline, apiculus prominent (up to 1 µm long), dextrinoid, cyanophilic in cotton blue. **Basidia** 45–60 × 8–9 µm, guttulate, cylindrical to clavate, with basal clamp-connections, tetra-sterigmate (6–12 µm long), with a longitudinal septum in between the sterigmata, granulate, (abnormally up to 22 µm long). **Hymenium** up to 35 µm wide, **Subhymenium** up to 50 µm wide. **Context** composed of parallelly arranged generative hyphae, hyphae septate, 3–5 µm wide,

hyaline, thin to slightly thick-walled (0.5 µm thick), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimens examined: India, Kerala State, Kozhikode District, Thusharagiri, 14 September 2017, Krishnapriya K., ZGCKP65.

Habitat: On soil, solitary, among leaf litter.

Comments: The morphology of the present specimen fits with the description of the species by Petersen (1987). *T. pusio* can be separated from *T. transpusio* by the less branched basidiomata with acerose apex, and the fusiform basidospores in the former (Petersen 1987). Also, the present specimen exhibit colour changes on bruising, which is absent in *T. transpusio* (Petersen 1987).

Tremellodendropsis tuberosa (Grev.) D.A. Crawford, Trans. & Proc. Roy. Soc. N.Z. 82: 619 (1954)

Basionym:
Merisma tuberosum Grev.

Synonyms:
Aphelaria tuberosa (Grev.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 192 (1950)
Clavaria gigaspora Cotton, Naturalist: 97 (1907)
Merisma tuberosum Grev., Scott. crypt. fl. (Edinburgh) 3: 178 (1824)
Polyozus contortus (P. Karst.) P. Karst., Revue mycol., Toulouse 3(no. 9): 22 (1881)
Stereum grantii Lloyd, Mycol. Writ. (Cincinnati) 7(Letter 73): 1314 (1924)
Stereum tuberosum (Grev.) Massee, Brit. Fung.Fl. (London) 1: 130 (1892)
Thelephora contorta P. Karst., Not. Sällsk. Fauna et Fl. Fenn. Förh. 9: 368 (1868)
Thelephora tuberosa (Grev.) Fr., Elench. fung. (Greifswald) 1: 167 (1828)

FIGURE 3

Basidiomata 70–80 × 2–4 mm thick, highly branched, with distinct stalk in some, often divided from the base, branches erect, main branches irregular, lateral branches dichotomous, long, erect (up to 30 mm long), slightly flattened, apex slightly spathulate to pyxidate, solid, ellipsoid in cross section, dull yellowish white, becomes brownish on drying, context fleshy, without any odour, no reaction on treatment with Fe_3Cl and KOH.

Basidiopsores 11–17 × 6–8 µm, (Q=1.3–2.1 µm, Q_m=1.7 µm), subfusiform to amygdaliform, with guttulate contents, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–50 × 8–10 µm, guttulate, clavate to cylindrical, without basal clamp-connection, transversely septate, bi-sterigmate (up to 9 µm long). **Hymenium** up to 80 µm wide. **Subhymenium** up to 40 µm wide. **Context** composed of generative hyphae, 4–5 µm wide, septate, hyaline, slightly thick-walled (0.5 µm), inamyloid, cyanophlic in cotton blue. Hyphal clamp-connection frequent.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 25 October 2019, Krishnapriya K., ZGCKP202; Kannur District, Aralam, 07 August 2021, Krishnapriya K., ZGCKP216.

Habitat: On soil, in gregarious groups among leaf litter.

Comments: The present specimen fits with the description of the species by Corner (1950), Crawford (1954) and KshamaTripathi *et al.* (2022). The present specimen resembles *T. flagelliformis*, but differs by the subglobose basidiospores, and needle like basidia with tetra- sterigmate in the latter (Corner 1966).

Tremellodendropsis flagelliformis (Berk.) D.A. Crawford, Trans. Roy. Soc. N.Z. 82(3): 621 (1954)

Basionym:
Clavaria flagelliformis Berk., in Hooker 1855

Synonyms:
Aphelaria flagelliformis (Berk.) Corner, Ann. Bot., Lond., n.s. 17: 350 (1953)
Aphelaria tasmanica (Lloyd) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 191 (1950)
Clavaria flagelliformis Berk., in Hooker, Bot. Antarct. Voy. Erebus Terror 1839-1843, II, Fl. Nov.-Zeal.: 186 (1855)
Lachnocladium flagelliforme (Berk.) Cooke, Grevillea 20(no. 95): 179 (1892)
Pseudotremellodendron pusio var. *tasmanicum* (Lloyd) D.A. Reid [as 'tasmanica'], Kew Bull. [11]: 535 (1957) [1956]
Pterula tasmanica Lloyd, Mycol. Writ. (Cincinnati) 7: 1227 (1923)
Tremellodendropsis flagelliformis var. *ovalispora* D.A. Crawford, Trans. Roy. Soc. N.Z. 82(3): 621 (1954)
Tremellodendropsis flagelliformis var. *tasmanica* (Lloyd) D.A. Crawford, Trans. Roy. Soc. N.Z. 82: 623 (1954)

FIGURE 4

Basidiomata 80 × 5 mm, branched, stalk up to 20 mm long, branches elongate, polychotomous below, dichotomous upwards, branches 2 mm wide, thick, cylindrical, with distinct stalk (up to 20 mm long), apex flattened when young, becoming acute when mature, hymenium rugulose, solid, terete in cross section, brownish-ochraceous with whitish apex, fleshy, with a pungent odour, turning brownish black on treatment with Fe_3Cl.

Basidiospores 9–10 × 8–9 µm (Q=1–1.12 µm, Q_m=1.11 µm), globose to subglobose, uniguttulate, smooth thin-walled, hyaline, apiculus prominent (up to 1 µm long), dextrinoid, cyanophilic in cotton blue. **Basidia** 45– 80 × 3–12 µm, guttulate, subclavate, with an apical expansion and relatively slender towards the base, ruptured after spore discharge, with septation, without basal clamp-connection, tetra-sterigmate (up to 12 µm long). **Hymenium** up to 120 µm wide. **Subhymenium** not distinct**. Cortex** composed of generative hyphae, 4–5 µm wide, septate, hyaline, slightly thick-walled (0.5 µm wide), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Kannur District, Aralam, 07 August 2021, Krishnapriya K., ZGCKP215.

Habitat: on soil, in gregarious groups, among leaf litter.

Comments: The present specimen fits with the description of the species by Corner (1966). *T. tuberosa* and *T. pusio* shows resemblance with the present specimen. *T. tuberosa* differs by its fusiform basidiospores and in being bi-sterigmate. *T. pusio* differs by its relatively less branched basidiomata with acerose apex, and fusiform basidiospores (Corner 1970; Petersen 1987).

Genus *Lachnocladium*

Basidiomata ramified, basidiospores smooth, hyphae uninflated, dicophyses and gloeocystidia present, clamp-connections absent.

Lachnocladium flavidum Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 696 (1950)

FIGURE 5

Basidiomata 90–100 × 1–2 mm, slender, polychotomously branched, branches arising from a basal mycelial patch, some fused towards the apex, apex acute, rarely bifurcate, solid, terete in cross section, glabrous, waxy, minutely pubescent towards the base, ochre to brownish grey, pale yellow towards the apex, context narrow, brittle when dry, with a distinct pleasant odour, turning blackish in KOH.

Basidiospores 3–4 × 3–4 µm (Q=1–1.4 µm, Q_m=1.3 µm), globose, subglobose or ellipsoid, agguttulate, smooth, thin-walled, hyaline, apiculus up to 0.5 µm long, inamyloid, cyanophilic in cotton blue. **Basidia** 15–27 × 3–5 µm, clavate, without basal clamp-connection, agutttulate, bi-sterigmate–4 (up to 8 µm long). **Gloeocystidia** present, 50–80 × 6–9 µm, projecting beyond the hymenium up to50 µm, cylindrical, flexuose, thin-walled, hyaline, with guttulate contents. **Hymenium** up to 20 µm wide, not thickening continuously. **Context** composed of two types of hyphae. **Medullary** hyphae generative, 3–5 µm wide, septate, thick-walled, yellowish, inamyloid, cyanophilic in cotton blue. **Cortex** with dichophyses 3–5 µm wide, dichotomous with pointed tips, thick-walled (up to 2 µm wide), yellowish-brown. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Thrissur District, Peechi, 20 October 2017, Krishnapriya K., ZGCKP76; Chimmney forest, 21 July 2021, Krishnapriya K., ZGCKP207; Kollam District, Thenmala, 23 September 2019, Krishnapriya K., ZGCKP186.

Habitat: On soil, in gregarious clusters, associated with *Terminalia paniculata*

Comments: The present specimen fits with the species description by Corner (1950). *L. fulvum* closely resembles the present specimen, but differs in the fusing pattern of the branches, and globose to subglobose basidiospores in the former. ITS sequence of the present specimen confirms its identity as *L. flavidum.*

Lachnocladium fulvum Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 696 (1950)

FIGURE 6

Basidiomata 70 × 2 mm, erect, with irregular branching (dichotomous or polychotomous), branches not fused, filiform, apex acute, glabrous to slightly pruinose, terete in cross section, solid, brownish with a deep yellow apex, becoming dark brown on bruising, context fleshy, slightly waxy, with a fungoid odour, turning blackish in KOH.

Basidiospores 3–4 × 2.5–3 µm (Q=1–1.3 µm, Q_m=1.2 µm), pip shaped, agguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 20–27 × 3–5 µm, clavate, without basal clamp-connection, agutttulate, bi-sterigmate–4 (up to 6 µm long). **Gloeocystidia** 50–100 × 7–12 µm, with large guttules, lageniform to utriform, thin-walled, hyaline. **Hymenium** 20 to 50 µm wide, irregularly thickened. **Context** differentiated in to medulla and cortex. **Medulla** composed of generative hyphae, 3 to 4 µm wide, thin- to slightly thick-walled (0.5 µm wide), inamyloid, cyanophilic in cotton blue. **Cortex** composed of dicophyses, which are arboriform, repeatedly branched, 3 to 4 µm wide. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Thrissur District, Chimmney, 20 July 2021, Krishnapriya K., ZGCKP206.

Habitat: Solitary, on the trunk of living *Cullenia* species.

Comments: The present specimen agree with the species description by Corner (1970). The Kerala collection is similar to *L. divaricatum* (Berk.) Pat. However, the hymenium of *L. divaricatum* thickens continuously and has very minute apiculus. The present specimen also shows similarity with *L. zonatum* Corner. But, differs by the smaller gloeocystidia (24–55 × 6–12 µm), and globose basidiospores of the latter (Corner 1950).

Genus *Gomphus*

Basidiomata unipileate to merismatoid, which are fan- to slightly funnel-shaped, deep violet to lavender, brownish to orangish yellow, hymenia wrinkled, basidiospores verrucose, basidiomata turning green in ferric chloride.

Gomphus zamorinorum Krishnapriya & T. K. A. Kumar *sp. nov.*

FIGURE 7

Basidiomata 30–40 × 5–10 mm, branched, branching (2–3) towards the apex, branching irregular, apex pyxidate, round or obtuse, not acute, two to three basidiomata in a cluster, not differentiated into stipe and pileus, young basidiomata cylindrical, arising from a thick rhizomorph like structure, glabrous to fibrillose, becomes partially lobed downwards on maturity, branched upwards, round, with broad hymenial folds or wrinkles, ellipsoid in cross section, solid, fragile, bright violet fruitbody, with a purplish tint towards the apex, no colour change on drying, context fleshy, with a pleasant odour, turning greenish in Fe_3Cl.

Basidiospores 6–7 × 4–5 µm (Q = 1.2–1.7 µm, Q_m = 1.4 µm), phaseoliform in side view, oblong in front view, with guttulate contents (uniguttulate), verrucose, thin to slightly thick-walled (0.5 µm), hyaline, apiculus prominent (up to 1 µm long), in some hilar appendage is protruded up to 6–7 µm long, inamyloid, cyanophilic in cotton blue. **Basidia** 25–50 × 4–7 µm, uniguttulate to agguttulate, cylindrical to clavate, incrustations present on the basidia, bi-sterigmate–4 (up to 4–7 µm long), cyanophilic in cotton blue. **Hymenial Cystidia** 21–60 × 5–6 µm, cylindrical to flexuose, projecting from the hymenium, thin-walled, inamyloid, pileocystidia absent. **Hymenium** 80–110 µm wide. **Subhymenium** not distinguishable. **Context** composed of interwoven, irregularly arranged, encrusted, and agglutinated hypahe, hyphal constrictions present, 4–8 µm wide, septate, blackish in group, gleophorous hyphae present, in some bulged at the septal portion (up to 11 µm), thin walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Wayanad District, Banasura sagar forest, 29 November 2019, Krishnapriya K., ZGCKP203.

Habitat: On soil, in gregarious clusters among leaf litter.

Comments: Slightly funnel shaped, merismatoid basidiomata, wrinkled hymenophore, verrucose basidiospores and hymenium turning greenish in Fe_3Cl confirms the placement of the present specimen in the genus *Gomphus.* The present specimen is similar to *G. clavatus* macroscopically in having wrinkled hymenophore with deep violet colour. However, it differs from the latter by its branched basidiomata, smaller basidiospores and basidia, absence of pileocystidia, presence of

gloeophorous hyphae and absence of clamp-connections from all parts. *G. clavatus* is the closest hit (76 %) in NCBI BLAST search using the two newly generated ITS sequences of the present specimen. Phylogenetic tree (Fig. 8) was constructed using these ITS sequences and those of Gomphaceae members retrived from Genbank (Table 5). *Calocera cornea* was taken as the out group. The present specimen clustered together within the *Gomphus* clade and appeared as a sister clade to *Gomphus clavatus* with 83% bootstrap support. Thus, we propose it as a new species *G. zamorinorum.*

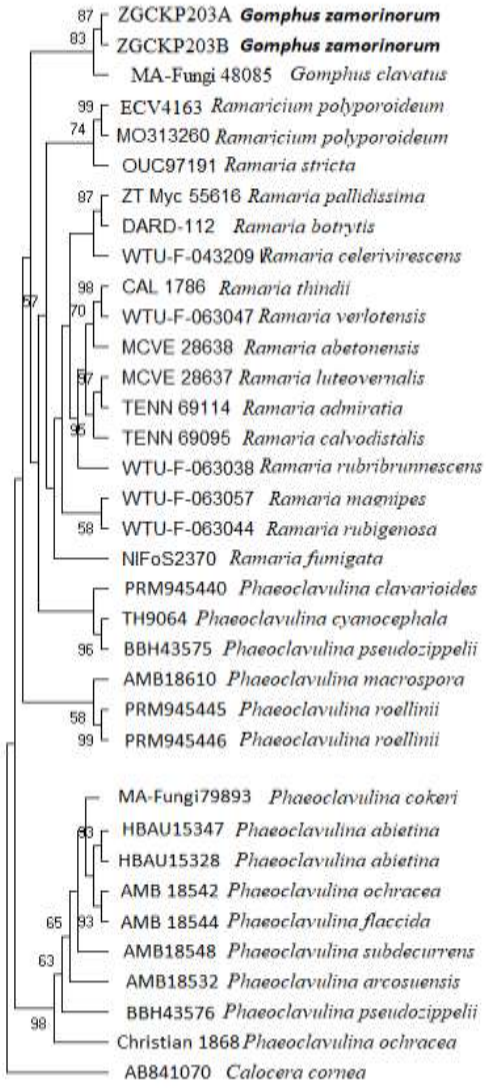


Fig.8: Phylogram generated from maximum likelihood analysis based on ITS sequence data showing the placement of *Gomphus zamorinorum.* The percentage of trees in which the associated taxa clustered together is shown next to the branches. Newly generated sequences are in bold.

Genus *Ramaria*

Basidiomata branched, colour ranges from white, yellow, orange, red, brilliant purple, brown, and green. Basidiospores smooth or echinulate, verrucose, rugulose or striate with yellow to ochraceous or brown coloured walls. Hyphae monomitic to rarely dimitic, uninflated, with or without clamp-connections, absence of cystidia, and positive hymenial reaction in ferric chloride.

Ramaria pusilla Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 617 (1950)

FIGURE 9

Basidiomata 30–40 × 8–10 mm, branched, branches dichotomous, fused at the base, glabrous, branches flattened, apex bifurcate to pyxidate, without distinct stalk, terete to ellipsoid in cross section, soild, white to cream, becoming pale pinkish on ageing, brownish on drying, immediate colour change on bruising (pink), context fleshy, without distinct odour, brownish in Fe_3Cl.

Basidiospores 4–5 × 3–4 µm, (Q=1–1.6 µm, Q_m=1.18 µm), broadly ellipsoid, uniguttulate, verrucose, slightly thick-walled (0.5 µm), apiculus prominent (1 µm), yellowish, inamyloid, cyanophilic in cotton blue. **Basidia** 20–30 × 4–5 µm, clavate, without basal clamp-connection, tetra-sterigmate (up to 7 µm). **Hymenium** up to 50 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 5 to 10 µm wide, septate, hyaline, slightly thick-walled (0.5 µm), hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzhi forest, 11 August 2017, Krishnapriya K., ZGCKP96.

Habitat: On soil, in caespitose clusters.

Comments: The present specimen fits with the species description by Corner (1950). *R. kunzei* resembles the present specimen by its whitish basidiomata, but differs in the presence of pip-shaped basidiospores and larger basidia in the former. Also, the colour changes while bruising in the present specimen is absent in the latter (Corner 1950).

Ramaria grandis (Peck) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 595 (1950)

Basionym:

Clavaria grandis Peck 1902

Synonyms:
Clavaria grandis Peck, Bull. Torrey bot. Club 29: 73 (1902) *Ramaria zippelii f. grandis* (Peck) R.H. Petersen, Taxonomy of Fungi, (Proc. int. Symp. Madras, 1973) Part 2 (Madras): 569 (1984)

FIGURE 10

Basidiomata 70 × 8 mm, branched, polychotomous below, dichotomous upwards, branches up to 5 mm wide, apex bifurcate, with a distinct 20 mm long stalk, deeply rooted, glabrous, pruinose towards base, solid, terete in cross section, greyish brown, whitish towards apex, colour changes to deeper shades on bruising, context fleshy, without any distinct odour, greenish in Fe_3Cl.

Basidiospores 9–11 × 5–7 µm, (Q=1.1–3 µm, Q_m=1.8 µm), obovoid to ellipsoid, guttulate, echinulate (spines up to 1 µm long), thick-walled (1 µm), yellowish, wall brownish, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–45 × 7–9 µm, with granulate contents, clavate, without basal clamp-connection, bi-sterigmate (up to 8 µm long). **Hymenium** up to 80 µm wide. **Subhymenium** up to 100 µm wide. **Context** composed of generative hyphae, 5–7 µm wide, septate, hyaline, slightly thick-walled (0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Malappuram District, Calicut University campus, 16 June 2022, Krishnapriya K., ZGCKP249.

Habitat: On soil, solitary to gregarious.

Comments: The present specimen fits with the description of *R. grandis* by Corner (1950). *R. apiculata* resembles *R. grandis*, but differs in the minutely verruculose basidiospores and tetra-sterigmate in the former (Corner 1950).

Ramaria divaricata (Peck) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 574 (1950)

Basionym:
Clavaria divaricata Peck 1887

Synonymy:
Clavaria divaricata Peck, Bull. N.Y. St. Mus. nat. Hist. 1(no. 2): 11 (1887)

FIGURE 11

Basidiomata 30–70 × 5–6 mm, branched, branches polychotomous below, dichotomous upwards, branches divaricate, apex acute to bifurcate, with a distinct stalk (20 mm long), solid, ellipsoid in cross section, glabrous, yellowish brown, branches yellow towards the apex, becoming darker on bruising and on drying, context fleshy, brittle, with a distinct pleasant odour, greenish in Fe_3Cl.

Basidiospores 10–14 × 4–5 µm (Q=1.6–3 µm, Q_m=2.5 µm), fusiform to lacrymoid, uniguttulate, echinulate to verrucose, thin- to slightly thick-walled (0.5 µm), apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 50–60 × 7–10 µm, granulate, clavate with basal clamp-connection, bi-sterigmate–4 (up to 7 µm long). **Hymenium** up to 60 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 4–9 µm wide, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Thusharagiri, 11 July 2019, Krishnapriya K., ZGCKP179.

Habitat: On soil, in gregarious groups.

Comments: The present specimen fits with the species description by Corner (1950). R. luteofusca is similar to the present specimen but differs by its smaller basidiospores (8–10 × 3–4 µm) and bi-sterigmate basidia (Corner 1950).

Ramaria gelatinosa Holmsk., Beata Ruris Otia Fungis Danicis 1: 81, tab. 20 (1790)

Synonym:

Clavaria gelatinosa Coker, The Clavarias of the United States and Canada: 137 (1923)

FIGURE 12

Basidiomata 50 × 7 mm, much branched, irregular branching, crowded, apex bifurcate, branching arising from the base, glabrous, cylindrical, terete in cross section, solid, gelatinous, creamy white to flesh coloured, becoming orangish brown on drying, apex concolourous to pale yellowish, context fleshy, with a pleasant odour, greenish in Fe_3Cl.

Basidiospores 7–10 × 5–7 µm, (Q=1.3–2 µm, Qm=1.6 µm), ellipsoid, with guttulate contents, verrucose, thick-walled (1 µm), hyaline, wall blackish, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–50 × 7–8 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 7 µm long). **Hymenium** up to 70 µm wide. **Subhymenium** up to 50 µm wide. **Context** composed of generative hyphae, 4–6 µm wide, septate, hyaline, inflated (up to 15 µm wide), thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 05 July 2019, Krishnapriya K., ZGCKP177.

Habitat: On decayed wood, solitary.

Comments: The present specimen fits properly with the species description of *R. gelatinosa* by Corner (1950). *R. subgelatinosa* resembles the present specimen by its gelatinous texture and microscopic characters, but differs in the apricot coloured basidiomata in the former (Corner 1950).

Ramaria suecica (Fr.) Donk, Rev. Niederl. Homob. Aphyll. 2: 105 (1933)

Basionym:

Clavaria suecica Fr. 1815

Synonyms:
Clavaria circinans Peck, Rep. (Annual) Trustees State Mus. Nat. Hist., New York 39: 43 (1887) [1886]
Clavaria suecica Fr., Observ. mycol. (Havniae) 1: 156 (1815)
Clavariella suecica (Fr.) P. Karst., Revue mycol., Toulouse 3(no. 9): 21 (1881)
Merisma suecicum (Fr.) Spreng., Syst. veg., Edn 16 4(1): 495 (1827)
Ramaria circinans (Peck) Marr & D.E. Stuntz, Biblthca Mycol. 38: 130 (1974) [1973]
Ramaria circinans var. *anceps* Marr & D.E. Stuntz, Biblthca Mycol. 38: 130 (1974) [1973]

FIGURE 13

Basidiomata 20–70 × 4–5 mm, branched, polychotomous, apex dichotomous to pyxidate, branchlets at base, base slightly tomentose with white mycelial patch, stalk up to 10 mm long, cylindrical, ellipsoid in cross section, solid, white when young, becoming cream to brownish with age, apex whitish, brownish on drying, context fleshy, brittle, with a pleasant odour, greenish in Fe_3Cl.

Basidiospores 9–11 × 4–5 µm (Q=1.1–2.2 µm, Q_m=1.6 µm), ellipsoid, aguttulate, verrucose, yellowish, slightly thick-walled (0.5 µm wide), blackish, apiculus prominent (up to 2 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 25–45 × 4–7 µm, clavate, with basal clamp-connections, tetra-sterigmate (up to 6 µm long). **Hymenium** up to 60 µm wide. **Subhymenium** up to 40 µm wide. **Context** composed of generative hyphae, 4–8 µm wide, agglutinated, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Mukkali, 05 July 2019, Krishnapriya K., ZGCKP176.

Habitat: On decayed wood, in gregarious clusters.

Comments: The present specimen fits with the description by Corner (1950). *R. conjunctipes* resembles the present specimen, but differs by the yellowish apex and echinulate basidiospores in the former.

Ramaria subaurantiaca Corner, Bull. Br. Mus. nat. Hist., Bot. 1(7): 200 (1955)

FIGURE 14

Basidiomata 70 × 15 mm, branched, branching irregular, with short and minute branchlets, apex blunt to pyxidate, orange, with yellowish apex, stalk solid,

whitish, arising from a white mycelial pad, context fleshy, without any odour, colour fades on bruising (yellowish), greenish in Fe_3Cl.

Basidiospores 10–15 × 5–6 µm (Q=1.3–2.5 µm, Q_m=1.8 µm), fusiform, with guttulate contents, echinulate, thick-walled (up to 1 µm), yellowish, wall blackish, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 7–9 µm, clavate, without basal clamp-connection, bi-sterigmate to 4 (up to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 100 µm wide. **Subhymenium** not distinct. **Context** composed of hyphae that are generative, 4–15 µm wide, inflated, septate, yellowish, slightly thick-walled (up to 0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., ZGCKP231.

Habitat: On soil, solitary, among leaf litter.

Comments: The present specimen fits with the description of *R. subaurantiaca* by Thind (1961). *R. flava* (Fr.) Quel. differs by its bright reddish-orange basidiomata, and smaller basidiopsores (7–10.5 × 4–5.3 µm, Thind 1961).

Ramaria fragillima (Sacc. & P. Syd.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 588 (1950)

Basionym:
Clavaria fragillima Sacc. & P. Syd. 1902

Synonyms:
Clavaria echinospora Henn., in Warburg, Monsunia 1: 141 (1899) [1900]
Clavaria fragillima Sacc. & P. Syd., Syll. fung. (Abellini) 16: 206 (1902)
Clavariella fragillima (Sacc. & P. Syd.) Overeem, Bull. Jard. bot. Buitenz, 3 Sér. 5: 275 (1923)

FIGURE 15

Basidiomata 90–120 × 9–10 mm, branched, branches stout, polychotomous below, dichotomous upwards, branches 6 mm wide, apex bifurcate, with a distinct stalk (up to 30 mm long), with a rooted base, arising from a white mycelial pad,

glabrous, slightly grooved, ellipsoid in cross section, solid, yellowish brown, orangish towards the apex, becoming brownish on drying, context fleshy, brittle, with a distinct pleasant odour, turning greenish in Fe_3Cl.

Basidiospores 10–15 × 5–6 µm (Q=1.5–3 µm, Q_m=2.1 µm), fusiform, with guttulate contents, echinulate (spines up to 1 µm long), slightly thick-walled (0.5 µm), yellowish with a black wall, apiculus prominent (1 to 2 µm long), inamyloid, cyanophilic in cotton blue. Spore print brown. **Basidia** 53–80 × 7–10 µm, clavate to broadly clavate without basal clamp-connection, 2 to 4 (up to 8 µm long), cyanophilic in cotton blue. **Hymenium** up to 70 µm wide. **Subhymenium** not distinctive. **Context** composed of generative hyphae, 3 to 8 µm wide, septate, yellowish, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Kozhikode District, Vanaparvam Bio Park, 18 July 2018, Krishnapriya K., ZGCKP139; Thusharagiri, 11 July 2019, Krishnapriya K., ZGCKP 181.

Habitat: on soil, solitary

Comments: *R. nigrescens* is similar to the present specimen by its ochraceous basidiomata with orangish tips, but differs by its much larger spores (12–20 × 5–8 µm), bi-sterigmate basidia and the presence of large crystals (Corner 1950). *R. subsigmoidea* microscopically resembles the present specimen, but differs by the basidiomata with yellowish tips in the latter (Corner 1950).

Ramaria subsigmoidea (Sacc. & P. Syd.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 628 (1950)

Basionym:
Clavaria subsigmoidea Sacc. & P. Syd. 1902

Synonyms:
Clavaria pamparum Speg., Anal. Mus. nac. B. Aires, Ser. 3 12: 280 (1909)
Clavaria pampeana Speg., Anal. Mus. nac. Hist. nat. B. Aires 6: 182 (1898) [1899]
Clavaria subsigmoidea Sacc. & P. Syd., Syll. fung. (Abellini) 16: 204 (1902)

FIGURE 16

Basidiomata 50 × 6 mm, branched, polychotomous below, dichotomous above, apex bifurcate, arising from a mycelial patch, glabrous, pruinose towards the base, cylindrical, solid, terete in cross section, flexuose, yellowish brown, yellowish towards the apex, context fleshy, with a pleasant odour, greenish in Fe_3Cl. Spore print dark brownish.

Basidiospores 6–9 × 4–5 µm, (Q=1.4–2.2 µm, Q_m=1.7 µm), ellipsoid, aguttulate, echinulate (up to 1 µm), slightly thick-walled (0.5 µm), brownish walls, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 27–32 × 6–7 µm, clavate, without basal clamp-connection, bi-sterigmate–4 (up to 7 µm long). **Hymenium** up to 30 µm wide. **Subhymenium** up to 100 µm wide. **Context** composed of generative hyphae, 3 to 6 µm wide, inflated up to 15 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode district, Vanaparvam Bio-Park, 18 July 2018, Krishnapriya K., ZGCKP140

Habitat: On soil, solitary.

Comments: The present specimen fits with the species description by Corner (1950). *R. flavo-alba* and *R. fragillima* are similar species. But, differs by the stout basidiomata with whitish stem and verrucose basidiospores in *R. flavo-alba*, and basidiomata with orangish tips and comaparatively larger basidiospores (10–15 × 5–6 µm) in *R. fragillima.*

Ramaria stricta (Pers.) Quél., Fl. mycol. France (Paris): 464 (1888)

Basionym:
Clavaria stricta Pers. 1795

Synonym:
Clavaria condensata Fr., Epicr. syst. mycol. (Upsaliae): 575 (1838) [1836-1838]
Clavaria condensata var. violaceotincta Bourdot & Galzin, Hyménomyc. de France (Sceaux): 98 (1928) [1927]
Clavaria kewensis Massee, J. Bot., Lond. 34: 153 (1896)
Clavaria pruinella Ces., in Rabenhorst, Fungi europ. extra-eur. exsicc.: 414 (1861)

Clavaria stricta Pers., Ann. Bot. (Usteri) 15: 33 (1795)
Clavaria stricta f. fumida (Peck) R.H. Petersen, Ramaria subgenus Lentoramaria with emphasis on North American taxa 43: 61 (1975)
Clavaria stricta var. fumida Peck, Rep. (Annual) Trustees State Mus. Nat. Hist., New York 41: 86 (1888)
Clavaria syringarum Pers., Mycol. eur. (Erlanga) 1: 164 (1822)
Clavariella condensata (Fr.) P. Karst., Bidr. Känn. Finl. Nat. Folk 37: 184 (1882)
Clavariella stricta (Pers.) P. Karst., Bidr. Känn. Finl. Nat. Folk 37: 188 (1882)
Corallium stricta (Pers.) G. Hahn, Pilzsammler, Edn 1: 73 (1883)
Lachnocladium odouratum G.F. Atk., Annls mycol. 6(1): 58 (1908)
Merisma strictum (Pers.) Spreng., Syst. veg., Edn 16 4(1): 495 (1827)
Ramaria concolour f. *fumida* (Peck) R.H. Petersen, Biblthca Mycol. 43: 61 (1975)
Ramaria condensata (Fr.) Quél., Fl. mycol. France (Paris): 467 (1888)
Ramaria stricta f. compacta M.P. Christ., Friesia 8(2): 150 (1968) [1967]
Ramaria stricta f. sambucina Franchi & M. Marchetti, Index Fungorum 457: 7 (2020)
Ramaria stricta f. violaceotincta (Bourdot & Galzin) Franchi & M. Marchetti, Index Fungorum 437: 1 (2020)
Ramaria stricta var. alba Cotton & Wakef., Trans. Br. mycol. Soc. 6(2): 174 (1919) [1918]
Ramaria stricta var. condensata (Fr.) Nannf. & L. Holm, in Lundell, Nannfeldt & Holm, Publications from the Herbarium, University of Uppsala, Sweden 17: 14 (1985)
Ramaria stricta var. laxiramosa Marr & D.E. Stuntz, Biblthca Mycol. 43: 140 (1974) [1975]

FIGURE 17

Basidiomata 30–70 × 5–6 mm, highly branched, irregular, polychotomous below, terminal branches dichotomous, apex bifurcate, erect, elongate, branches narrower (2–3 mm wide), slightly grooved, arising from a mycelial patch, distinct stalk when young (up to 10 mm long), cylindrical, glabrous, solid, terete in cross section, creamy white becoming ochraceous to flesh coloured on aeging, creamy white towards apex, becoming brownish on aging, context brittle, fleshy, with a distinct pleasant odour, greenish in Fe_3Cl.

Basidiospores 9–10 × 4–5 µm, (Q=1.2–1.8 µm, Q_m=1.5 µm), ellipsoid, agguttulate to biguttulate, smooth to verruculose, thick-walled (1 µm), yellowish, wall blackish, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–50 × 7–10 µm, clavate, without basal clamp-connection, sterigmata 2 to 4 (up to 7 µm long). **Hymenium** up to 80 µm wide. **Subhymenium** up to 40 µm wide. **Context** composed of parallely arranged generative hyphae, 4–7 µm wide, septate, thin- to thick-walled (up to 1 µm), pale yellowish, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimen examined: India, Kerala State, Kannur District, Aralam, 28 June 2010, Krishnapriya K., ZGCKP170.

Habitat: On dead wood, caespitose in gregarious groups.

Comments: The present specimen fits with the description by Corner (1950). *R. gracilis* is similar to the present specimen by its creamy whitish basidiomata, but differs in smaller basidospores (6–8 × 4–5 µm) and inflated hyphae of the former.

Ramaria gracilis (Pers.) Quél., Fl. mycol. France (Paris): 463 (1888)

Basionym:
Clavaria gracilis Pers. 1797

Synonyms:
Clavaria fragrantissima G.F. Atk., Annls mycol. 6(1): 57 (1908)
Clavaria gracilis Pers., Comm. fung. clav. (Lipsiae): 50 (1797)
Clavaria stricta var. *alba* Cotton & Wakef., Trans. Br. mycol. Soc. 6(2): 174 (1919) [1918]
Clavariella gracilis (Pers.) P. Karst., Revue mycol., Toulouse 3(no. 9): 21 (1881)
Merisma gracile (Pers.) Spreng., Syst. veg., Edn 16 4(1): 496 (1827)

FIGURE 18

Basidiomata 70–80 × 4–5 mm, branched, branching dichotomous, branches up to 3 mm wide, apex subulate or bifurcate, glabrous, slightly pruinose towards the apex, base flexuose, arising from a white mycelial patch, solid, terete in cross section, white to cream, apex paler, ochraceous brown on aging, no colour changes on bruising, context fleshy, with a pleasant odour, greenish in Fe_3Cl.

Basidiospores 6–8 × 4–5 µm (Q=1.1–1.6 µm, Q_m=1.35 µm), ellipsoid, with guttulate contents, rough to nearly smooth, slightly thick-walled (0.5 µm wide), wall brownish, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 20–40 × 6–7 µm wide, clavate, without basal clamp-connection, tetra-sterigmate (up to 6 µm long). **Hymenium** up to 100 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, inflated up to 16 µm wide, thin to thick-walled (0.5 to 1 µm wide), hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 28 June 2019, Krishnapriya K., ZGCKP162.

Habitat: On a twig, gregarious.

Comments: *R. flaccida* resembles the present specimen, but differs by its echinulate basidiospores and uninflated hyphae.

Genus *Phaeoclavulina*

Basidiomata branched to merismatoid. Colour ranges from white, yellowish brown, orange, green, olivaceous, blue-green, violet, brown, red cinnamon, brick red to gray. Basidiospores echinulate or verrucose. Basidia two to four sterigmate. Hyphae monomitic, with clamp-connections, gleopherous hyphae present. Crystalloid elements present in some species.

Phaeoclavulina cyanocephala (Berk. & M.A. Curtis) Giachini, Mycotaxon 115: 191 (2011)

Basionym:
Clavaria cyanocephala Berk. & M.A. Curtis 1868

Synonymy:
Clavaria cyanocephala Berk. & M.A. Curtis, J. Linn. Soc., Bot. 10(no. 46): 338 (1868) [1869]
Ramaria cyanocephala (Berk. & M.A. Curtis) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 568 (1950)
Ramaria grandis f. cyanocephala (Berk. & M.A. Curtis) R.H. Petersen, Biblthca Mycol. 79: 71 (1981)

FIGURE 19

Basidiomata 100–130 × 20–40 mm, branched, main branches irregular, lateral and terminal branches dichotomous, narrower towards the apex, becoming acute, bifurcate, stalk distinct, arising from a mycelial pad, solid, cylindrical, terete in cross section, pruinose throughout, slightly ridged, brown, with a lilac tinge, dark brownish on drying, bluish towards the apex, context fleshy, smoke grey on treatment with Fe_3Cl, odour not distinct, spore print brown.

Basidiospores 13–16 × 8–10 µm, (Q=1.6–2 µm, Qm=1.64 µm), ellipsoid to amygdaliform, uniguttulate, echinulate (spines 3 to 4 µm long), thick-walled, yellowish, apiculus prominent (3 to 4 µm long), dextrinoid, cyanophilic in cotton blue. **Basidia** 40–60 × 9–10 µm, agguttulate, clavate, without basal clamp-connection, bisterigmate (8 to 11 µm long), cyanophilic in cotton blue. **Hymenium** 50 to 60 µm wide, **Subhymenium** not distinctive. **Context** composed of parralelly arranged

generative hyphae, 4 to 10 µm wide, septate, thin- to slightly thick-walled, hyaline, gleopherous hyphae 3–4 µm wide, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimens examined: India, Kerala State, Malappuram District, Calicut University campus, 28 June 2018, Krishnapriya K., KPZGC114; Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., KPZGC229; Malappuram District, Calicut University campus, 16 June 2022, Krishnapriya K., KPZGC248.

Habitat: On soil, in gregarious clusters.

Comments: *P. cyanocephala* can be easily distinguished from the field by its large basidiomata with bluish tips (Maneevun *et al*. 2012).

Phaeoclavulina cokeri (R.H. Petersen) Giachini, Mycotaxon 115: 190 (2011).

Basionym:
Ramaria cokeri R.H. Petersen 1976

Synonymy:
Ramaria cokeri R.H. Petersen, Dist. Hist. Biota S. Appalachians, 4. Algae and Fungi (Charlottesville): 291 (1976)

FIGURE 20

Basidiomata 100–120 × 10–20 mm, highly branched, polychotomous below, dichotomous upwards, apex dichotomous to pyxidate, branches pruinose, slightly ridged, solid, terete in cross section, yellowish, becoming yellowish brown with age, brighter towards the apex, context fleshy, odour indistinct, turning greenish in Fe_3Cl.

Basidiospores 10–15 × 6–8 µm (Q=1.4–2.1 µm, Q_m=2.7 µm), lacrymoid to fusiform, with guttulate contents (mostly single large oil droplet), echinulate (up to 1 µm long), thick-walled (up to 1 µm), yellowish, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–60 × 7–10 µm, guttulate, clavate, with basal clamp-connection, 2 to 4 (up to 8 µm long), cyanophilic in cotton blue. **Hymenium** up to 100 µm wide. **Subhymenium** up to 40 µm wide, subhymenial hyphae that are thick-walled (up to 4 µm wide), yellowish. **Context** composed of generative hyphae, up to 10 µm wide, septate, thin-walled, hyaline, gleopherous

hyphae present, 4–5 µm wide, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., ZGCKP228; ZGCKP238

Habitat: On soil and on dead wood, solitary.

Comments: The present specimen shows similarity with *R. divaricata* (Peck) Corner microscopically, but differs from the intensive yellowish basidiomata with divaricate branches of the latter (Corner 1950). It also resembles *R. tubulosa* (Fr.) Corner microscopically, but differs by yellowish basidiomata in the latter.

Genus *Trechispora*

Basidiomata coralloid, white to creamy, pink or purplish. Basidiospores small, angularly ellipsoid, verrucose, basidia small. Hyphae monomitic, with clamp-connections, cystidia absent.

Trechispora foetida (A.N.M. Furtado & M.A. Neves), L.W. Zhou & S.L. Liu, in Liu, He, Wang, May, He, Chen & Zhou, Mycosphere 13 (1): 912 (2022)

Synonymy:

Scytinopogon foetidus A.N.M. Furtado & M.A. Neves, IN Furtado, Daniels, Reck & Neves, *Mycotaxon* 136(1): 119 (2021).

FIGURE 21

Basidiomata 30–60 × 3–5 mm, branched, branches erect, polychotomous below, dichotomous upwards, branches cylindrical, with a distinct stalk, up to 20 mm long, glabrous, solid, terete in cross section, apex bifurcate, purple to dark brown, stalk whitish with a purple tinge, context fleshy, with an unpleasant odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=0.8–1.2 µm Q_m=1 µm), ellipsoid, angular, guttulate, verrucose to warty, thin-walled, hyaline, apiculus not prominent, inamyloid,

cyanophilic in cotton blue. **Basidia** 20–25 × 8–9 µm, aguttulate, broadly clavate, with basal clamp-connection, tetra-sterigmate (up to 5 µm long). **Hymenium** 30 µm wide. **Subhymenium** up to 50 µm wide. **Context** composed of generative hyphae, 3–8 µm wide, septate, hyaline, thin- to slightly thick-walled (up to 0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 28 June 2019, Krishnapriya K., ZGCKP161.

Habitat: On soil, in gregarious groups**.**

Comments: The present specimen fits with the species description of *Scytinopogon foetidus* (now *T. foetida*) by Corner (1970) and Furtado *et al.* (2021). Morphologically, it resembles *T. havencampii* Desjardin & B.A. Perry, but differs by the bi-sterigmate basidia of the latter (Furtado *et al*. 2021). Currently, *Scytinopogon* is synonymized within the genus *Trechispora* (Liu *et al*. 2022; Meiras-Ottoni 2021), and the species has been recombined as *T. foetida* by Liu *et al.* (2022). In the phylogenetic analysis conducted using the newly generated ITS sequence (Table 8), the present specimen nested with the *T. foetida* sequence from Brazil with 95% BS support (Fig. 28).

Trechispora dealbata (Berk.) L.W. Zhou & S.L. Liu, inLiu, He, Wang, May, He, Chen & Zhou, Mycosphere 13 (1): 911 (2022)

Basionym:
Clavaria dealbata Berk. 1856

Synonyms:
Clavaria dealbata Berk., Hooker's J. Bot. Kew Gard. Misc. 8: 275 (1856)
Lachnocladium dealbatum (Berk.) Cooke, Grevillea 20(no. 93): 10 (1891)
Ramariopsis dealbata (Berk.) R.H. Petersen, Persoonia 12(3): 230 (1984)
Scytinopogon dealbatus (Berk.) Corner, Beih. Nova Hedwigia 33: 89 (1970)

FIGURE 22

Basidiomata 80 × 4 mm, branched, branches polychotomous below, dichotomous above, branches up to 3 mm wide, erect, apex bifurcate, with a distinct stalk, 15 mm long, glabrous, solid, cylindrical, terete in cross section, white, with a

pale pink tinge, brownish on drying, context fleshy, brittle, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 4–5 × 3–4 µm (Q=1–1.5 µm Q_m=1.3 µm), ellipsoid, angular, uniguttulate, echinulate (spines up to 0.5 µm long), slightly thick-walled (0.5 µm), apiculus not prominent, inamyloid, cyanophilic in cotton blue. **Basidia** 15–25 × 6–7 µm, agguttulate, broadly clavate to cylindrical, with basal clamp-connection, sterigmata 2 to 4 (up to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 100 µm wide. **Subhymenium** up to 20 µm wide. **Context** composed of generative hyphae, 3 to 15 µm wide, agglutinated, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Malappuram District, Nilambur Teak Museum, 03 July 2018, Krishnapriya K., ZGCKP135

Habitat: on soil, solitary among leaf litter.

Comments: Species description of the present collection matches with that of *Scytinopogon dealbatus* (now *T. dealbata*) described by Corner (1970) and Furtado *et al*. (2021). *S. scaber* resembles the present specimen by its whitish basidiomata, but differs by its papillate branches. The ITS sequence of the Kerala collection confirms its identity as *T. dealbata* in NCBI BLAST search with 95 % identity with *T. dealbata* sequence from Brazil. In the phylogenetic tree constructed, the Kerala collection nested with the *T. dealbata* collection from Brazil with 100% BS (Fig. 28).

Trechispora havencampii (Desjardin & B.A. Perry) Meiras-Ottoni & Gibertoni, in Meiras-Ottoni, Larsson & Gibertoni, Mycol. Progr. 20(2): 215 (2021)

Synonymy:

Scytinopogon havencampii Desjardin & B.A. Perry, Mycosphere 6(2): 435 (2015)

FIGURE 23

Basidiomata 40–90 × 5–6 mm, densely branched, bushy, polychotomous below, dichotomous upwards, 3 mm wide, apex dichotomous, with a distinct stalk, stalk up to 30 mm long, solid, ellipsoid in cross section, pruinose, branches purple,

whitish at the extreme apex, yellowish brown towards and at the stalk, context fleshy, without any distinct odour, no reaction in KOH and Fe_3Cl.

Basidiospores 6–7 × 4–6 µm (Q=1–1.5 µm Q_m=1.3 µm), ellipsoid, angular, uniguttulate, verruccose, slightly thick-walled, apiculus not prominent, inamyloid, cyanophilic in cotton blue. **Basidia** 18–27 × 9–10 µm, agguttulate, broadly clavate, with basal clamp-connection, bi-sterigmate (4 to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 80 µm wide, **Subhymenium** up to 100 µm wide. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, hyaline, thin-walled, ampulliform swelling at septa (up to 15 µm wide), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Kannur District, Aralam Wild Life Sanctury, 28 June 2019, Krishnapriya K., ZGCKP160.

Habitat: On soil in gregarious clusters among dead and decayed leaf litter.

Comments: The present specimen fits with the species description of *S. havencampii* (now T. *havencampii*) by Desjardin & Perry (2015). *T. robusta* shows phenotypic similarity with the present specimen, but differs by the tetra-sterigmate basidia in the former (Corner 1970). NCBI BLAST search conducted using the the newly generated ITS sequence of the Kerala collection shows 95 % identity with *T. havencampii* sequence from U.S.A. In the phylogenetic tree constructed, the present specimen was nested with the *T. havencampii* from U.S.A. with 100% BS.

Trechispora robusta (Rick) L.W. Zhou & S.L. Liu, inLiu, He, Wang, May, He, Chen & Zhou, Mycosphere 13 (1): 911 (2022)

Basionym:
Clavaria robusta Rick 1931

Synonyms:
Clavaria robusta Rick, Egatea 16: 120 (1931)
Scytinopogon robustus (Rick) Corner, Beih. Nova Hedwigia 33: 91 (1970)

FIGURE 24

Basidiomata 70–80 × 5–6 mm, branched, polychotomous below, dichotomous upwards, apex bifurcate, pruinose, with a distinct stalk in some (up to 30 mm long), base tomentose, cylindrical, solid, ellipsoid in cross section, greyish white, tip concolourous, becoming brownish black on drying, context fleshy, without any odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 4–5 µm (Q=1.2–1.7 µm Q_m=1.4 µm), ellipsoid, angular, guttulate, echinulate to verruccose (spines up to 0.5 µm long), slightly thick-walled (0.5 µm), hyaline, apiculus not prominent, inamyloid, cyanophilic in cotton blue. **Basidia** 20–30 × 5–10 µm, agguttulate, broadly clavate, with basal clamp-connection, bi-sterigmate to 4 (3 to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 50 µm wide, **Subhymenium** up to 30 µm wide. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Kozhikode District, The Zamorin's Guruvayurappan College campus, 02 July 2018, Krishnapriya K., ZGCKP131; Malappuram District, Nilambur Teak Museum, 03 July 2018, Krishnapriya K., ZGCKP134.

Habitat: On soil, in gregarious clusters among leaf litter.

Comments: The present specimen is identified as *Scytinopogon robustus* (now *T. robusta* (Liu *et al.* 2022)) from the species description by Corner (1950). *S. pallescens* (Bres.) Singer is similar to the present specimen, but differs by its white basidiomata, pyxidate branch apex, and by the presence of calcium oxalate crystals inside the hyphae (Corner 1970). NCBI BLAST search using the newly generated ITS sequence of the present specimen shows 96% identity with *T. robusta* sequence from China. The phylogenetic analysis done using the above sequence of the Kerala collection nested with *T. robusta* collection from China with 95% BS (Fig. 28).

Trechispora angulispora ((Berkeley) Corner) krishnapriya & T. K. A. Kumar, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 311 (1950)

Basinonym:

Clavaria angulispora Pat., in Patouillard & Gaillard 1888

Synonyms:

Clavaria angulispora Pat., in Patouillard & Gaillard, Bull. Soc. mycol. Fr. 4(2): 41 (1888)
Clavaria connata Berk., Hooker's J. Bot. Kew Gard. Misc. 8: 275 (1856)
Scytinopogon angulisporus (Pat.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 648 (1950)
Scytinopogon angulisporus var. *curtus* Corner, Ann. Bot., Lond., n.s. 16: 701 (1950)
Scytinopogon angulisporus var. gracilis Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 701 (1950)

FIGURE 25

Basidiomata 40–60 × 2–3 mm, branching irregular, polychotomous below, dichotomous upwards, terminal branches are fused in some, apex dichotomous to pyxidate, branches elongate, with distinct stalk (up to 20 mm long), slightly rigid, arising from prominentat white mycelial strands that are usually found attached to the substratum, ellipsoid in cross section, solid, sterile towards the apex, white, becoming ochraceous on drying, distinct fungoid odour, context fleshy, no positive reaction in Fe_3Cl and KOH.

Basidiospore 5–7 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.3 µm), ellipsoid, angular, verrucose, aguttulate to guttulate, slightly thick-walled (0.5 µm), wall greyish, apiculus not prominent, hyaline, inamyloid, cyanophilic in cotton blue. **Basidia** 25–35 × 6–7 µm, guttulate, cylindrical to clavate, with basal clamp-connection, tetra-strigmate (up to 5 µm long). **Hymenium** up to 200 µm wide. **Subhymenium** up to 50 µm wide. **Context** composed of generative hyphae, 3 to 8 µm wide, inflated up to 15 µm wide, interwoven, septate, hyaline, slightly thick-walled (0.5 µm). Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Pokkunnu, 10 July 2017, Krishnapriya ZGCKP36; 18 July 2017; Krishnapriya ZGCKP40, ZGCKP44; 02 September 2013, Binusha VB9; Kozhikode District, Thamarassery, 24 June 2022, Krishnapriya K., ZGCKP255.

Habitat: On soil, in gregarious clusters.

Comments: The characters of the present specimen fit with the species description of *S. angulisporus* (now *C. connata*) by Corner (1950). The present specimen may get confused with *Ramariopsis kunzei* by the whitish basidiomata, but can be differentiated by the angular ellipsoid basidiospores in the former (Corner 1950).

The phylogenetic tree constructed using the newly generated ITS sequence (Table 8) of the present specimen got positioned within the *Trechispora* clade, along with other two *Scytinopgon* species from India with 97% BS. (Fig. 28). Hence, we recommend a nomenclatural change for *C. connata* as *T. angulispora*.

Trechispora cystidiata Krishnapriya & T. K. A. Kumar *sp. nov.*

FIGURE 26

Basidiomata 70–80 × 5–6 mm, fragile, branched, main branches polychotomous, terminal and lateral branches dichotomous, with a distinct stalk, up to 5 mm high, arising from a white mycelial patch, glabrous, ellipsoid in cross section, solid, apex pyxidate, pale brown, becomes purplish towards the apex, apex white, tomentose at the base, context fleshy, with a pleasant odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 6–7 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.3 µm), ellipsoid, angular, agguttulate to uniguttulate, verruccose, thin walled, hyaline, apiculus not prominent, inamyloid, cyanophilic in cotton blue. **Basidia** 22–38 × 5–8 µm, guttulate, clavate to cylindrical, with basal clamp-connection, tetra-sterigmate (up to 6 µm long), cyanophilic in cotton blue. **Cystidia** 40–60 × 5–6 µm, fusiform to utriform, thin-walled, hyaline, inamyloid. **Hymenium** 60 to 80 µm wide, **Subhymenium** not distinguishable. **Context** composed of generative hyphae, 4–6 µm wide, septate, hyaline, thin- to slightly thick-walled (0.5 µm), inflated up to 18 µm wide, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connetions present, not frequent.

Specimen examined: India; Kerala State, Kozhikode district, Pokkunu, 18 June 2020, Krishnapriya KP151; 15 July 2021, Krishnapriya KP212.

Habitat: On soil, in association with *Terminalia* species, solitary.

Comments: *T. echinospora, T. foetida* and *T. havencampii* are the clavarioid species with pigmented basidiomata in the genus *Trechispora. T. echinospora* differs from the present specimen by its smaller, thin branched, purple basidiomata, echinulate basidiospores, bi-sterigmate basidia and, absence of cystidia. *T. foetida* differs by its dark brownish basidiomata, with whitish stalk, uninflated hyphae and absence of cystidia in it. *T. havencampii* is distinct by its purple basidiomata, bi-sterigmate basidia, ampullaceous septa and absence of cystidia. *T. havencampii* was the closest hit in NCBI BLAST search (80%) using the newly generated ITS sequences. Phylogenetic tree (Fig. 28) constructed using the ITS sequences of the present specimen nested as a sister clade to *T. havencampii* with only 85% BS. Both morphological and molecular characterization shows the uniqness of the present specimen. Thus, we propose it as a novel species, *T. cystidiata*.

Trechispora corneri ((Berkeley) Corner) Krishnapriya & T. K. A. Kumar, *nomen. novum.*

Basionym:
Clavaria echinospora Berk. & Broome 1873

Synonyms:
Clavaria echinospora Berk. & Broome, J. Linn. Soc., Bot. 14(no. 74): 75 (1873) [1875]
Scytinopogon echinosporus (Berk. & Broome) Corner, Annals of Botany Memoirs 1: 655 (1950) [MB#305706]

FIGURE 27

Basidiomata 50 × 2 mm, branched, repeatedly dichotomous, apex bifid to pyxidate, with a distinct stalk, up to 10 mm long, arising from a white mycelial mat, glabrous, solid, ellipsoid in cross section, purple, stalk brownish, whitish at the extreme apex, context fleshy, with a distinct odour, no positive reaction in Fe_3Cl and KOH.

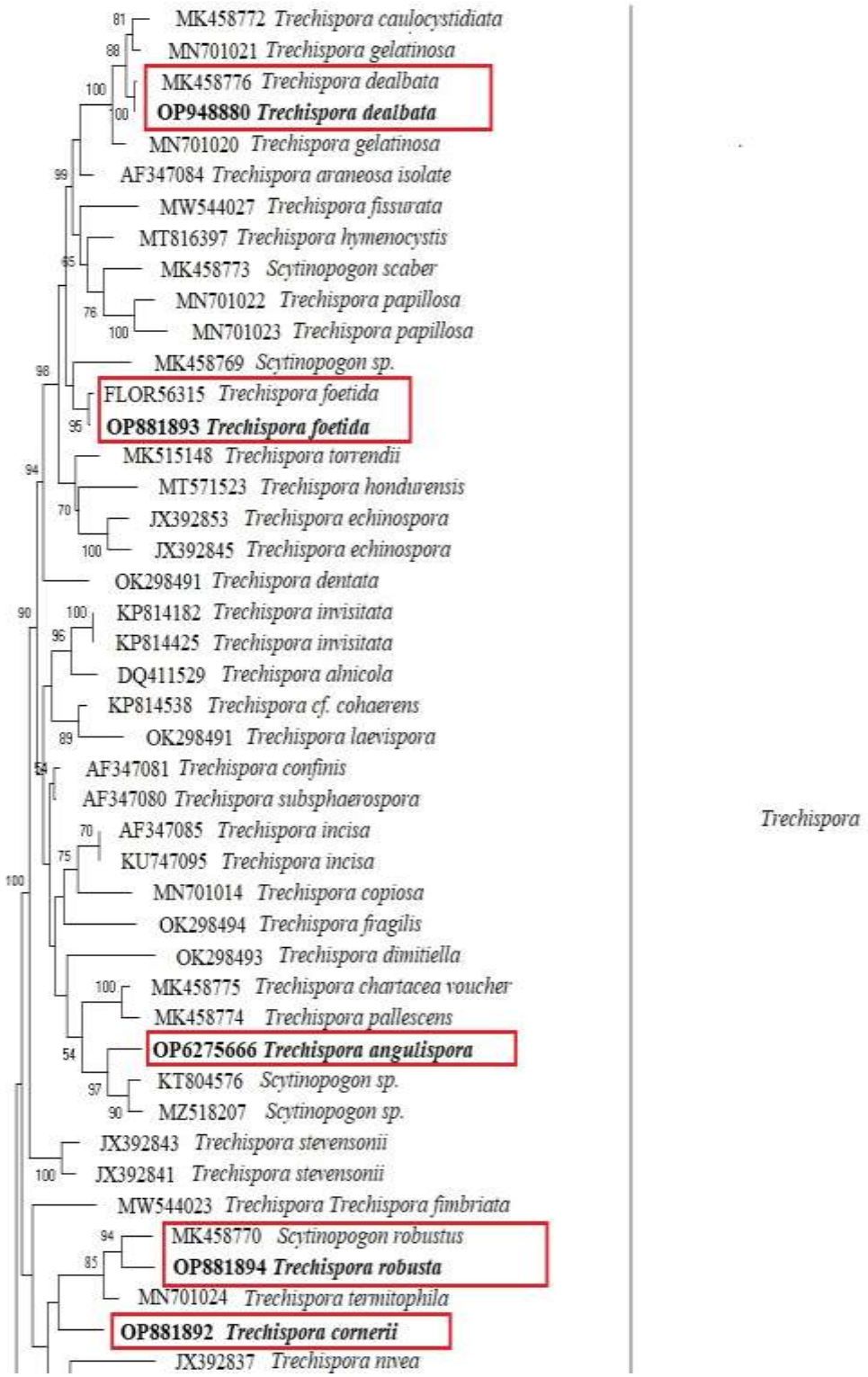
Basidiospores 4–7 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.29 µm), ellipsoid, angular, uniguttulate, echinulate (spines up to 0.5 µm), thin-walled, hyaline, apiculus not prominent, inamyloid, cyanophilic in cotton blue. **Basidia** 20–30 × 5–6 µm, clavate to broadly clavate, with basal clamp-connection, bi-sterigmate, (up to 5 µm long). **Hymenium** up to 40 µm wide. **Subhymenium** not distinct. **Context** composed

of parallely arranged generative hyphae, 4–12 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., ZGCKP237.

Habitat: On soil, solitary.

Comments: The present specimen fits with the species description of *S. echinosporus* by Corner (1950) and Furtado *et al.* (2021). Although the species should have been considered as belonging to *Trechispora* according to the synonimization of *Scytinopogon* with *Trechispora* based on Liu *et al.* (2022) and Furtado *et al.* (2021), due to the lack of moleculare evidence, a formal genus transfer is yet to be done. Hence, a phylogenetic study was conducted using the newly generated ITS sequence of the present species (Fig. 28). The phylogenetic tree clearly confirms the placement of the present specimen within the *Trechispora* clade. However, a species with the same epithet (*echinospora*) already exists in the genus *Trechispora* (a resupinate species *T. echinospora*, Fungal Diversity Notes 2019). Thus, a *nomen. novem,* (*T. corneri* ((Berkeley) Corner) Krishnapriya & T. K. A. Kumar, '*corneri*' in recognition of the original author E. J. H. Corner) is to be proposed.


MK458772 Trechispora caulocystidiata
MN701021 Trechispora gelatinosa
MK458776 Trechispora dealbata
OP948880 Trechispora dealbata
MN701020 Trechispora gelatinosa
AF347084 Trechispora araneosa isolate
MW544027 Trechispora fissurata
MT816397 Trechispora hymenocystis
MK458773 Scytinopogon scaber
MN701022 Trechispora papillosa
MN701023 Trechispora papillosa
MK458769 Scytinopogon sp.
FLOR56315 Trechispora foetida
OP881893 Trechispora foetida
MK515148 Trechispora torrendii
MT571523 Trechispora hondurensis
JX392853 Trechispora echinospora
JX392845 Trechispora echinospora
OK298491 Trechispora dentata
KP814182 Trechispora invisitata
KP814425 Trechispora invisitata
DQ411529 Trechispora alnicola
KP814538 Trechispora cf. cohaerens
OK298491 Trechispora laevispora
AF347081 Trechispora confinis
AF347080 Trechispora subsphaerospora
AF347085 Trechispora incisa
KU747095 Trechispora incisa
MN701014 Trechispora copiosa
OK298494 Trechispora fragilis
OK298493 Trechispora dimitiella
MK458775 Trechispora chartacea voucher
MK458774 Trechispora pallescens
OP6275666 Trechispora angulispora
KT804576 Scytinopogon sp.
MZ518207 Scytinopogon sp.
JX392843 Trechispora stevensonii
JX392841 Trechispora stevensonii
MW544023 Trechispora Trechispora fimbriata
MK458770 Scytinopogon robustus
OP881894 Trechispora robusta
MN701024 Trechispora termitophila
OP881892 Trechispora cornerii
JX392837 Trechispora nivea
Trechispora

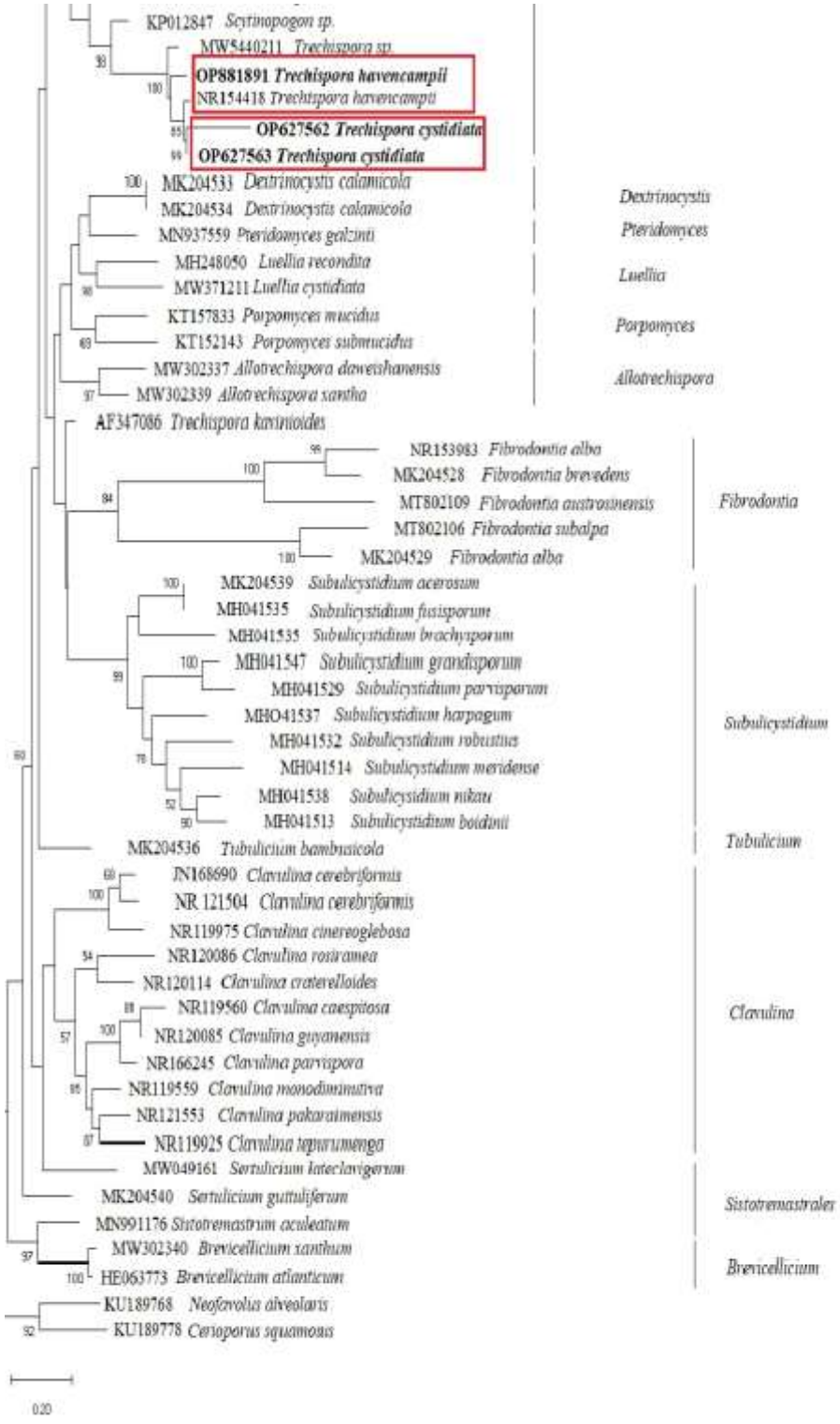


Fig. 28: Maximum Likelihood tree generated using the ITS sequence data. Values at the nodes indicate the ML bootstrap values. BS value above 50% are shown. Newly generated sequences are indicated in bold.

Genus *Aphelaria*

Basidiomata branched, pale brownish to greyish brown. Basidiospores smooth, hyaline. Basidia aseptate. Cystidia absent. Hyphae monomitic, without clamp-connections.

Aphelaria dendroides (Jungh.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 182 (1950)

Basionym*:*
Clavaria dendroides Jungh. 1838

Synonyms:
Clavaria dendroides Jungh., Verh. Batav. Genootsch. Kunfst. Wet. 17(2): 33 (1838)
Clavaria lurida Kalchbr., Proc. Linn. Soc. N.S.W. 7(1-2): 105 (1882)
Clavaria ornithopoda Massee, Bull. Misc. Inf., Kew: 154 (1901)
Lachnocladium dendroides (Jungh.) Sacc. & P. Syd., Syll. fung. (Abellini) 16: 213 (1902)
Lachnocladium kurzii Berk. ex Cooke, Grevillea 20(no. 93): 11 (1891)
Merisma dendroides (Jungh.) Lév., Annls Sci. Nat., Bot., sér. 3 5: 157 (1846)
Pterula dendroides (Jungh.) Fr., Nova Acta R. Soc. Scient. upsal., Ser. 3 1(1): 117 (1851) [1855]
Thelephora bidentata Pat., Ann. Jard. Bot. Buitenzorg, suppl. 1: 115 (1897)
Thelephora dendroides (Jungh.) Lév., Annls Sci. Nat., Bot., sér. 3 2: 209 (1844)
Tremellodendropsis lurida (Kalchbr.) R.H. Petersen, Mycotaxon 29: 63 (1987)

FIGURE 29

Basidiomata 80–90 × 2–3 µm, branching irregular, polychotomous, branching sparse towards the apex, apex acute, glabrous to pruinose, with a distinct stalk (up to 20 mm long), cylindrical, solid, terete in cross section, stalk pale brownish, greyish brown upwards, becoming darker on bruising and drying, context fleshy, with a distinct fungoid odour, branches of separate basidiomata sometimes fused, no positive reaction in Fe_3Cl and KOH.

Basidiospores 8–10 × 7–9 µm (Q=0.8–1.2 µm Q_m=1.5 µm), subglobose to globose, aguttulate to uniguttulate, smooth, thin-walled, hyaline, with a slight blackish wall, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 38–60 × 7–11 µm, guttulate, abruptly clavate, without basal clamp-connection, collapsing after spore discharge, sterigmata 2 to 4 (up to 10 µm long), mostly bi-sterigmate. **Hymenium** up to 100 µm wide. **Subhymenium** up to 40 µm wide. **Context** composed of generative hyphae, 5–6 µm wide, septate, interwoven,

thin- to slightly thick-walled (0.5 µm wide), yellowish, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Janaki forest, 02 October 2019, Krishnapriya K., ZGCKP194.

Habitat: On soil, in gregarious groups.

Comments: *A. dendroides* may be misidentified as a *Tremellodendropsis flagelliformis* by its basidiomatal morphology. The branching pattern and slightly rigid hymenophore of *A. dendroides* resembles those of *T. flagelliformis*, but differs by the presence of septate basidia, and presence of hyphal clamp-connections in the latter.

Genus *Clavulina*

Basidiomata simple to coralloid with amphigenous hymenia, basidia aseptate to septate, bi-sterigmate, basidiospores smooth, hyaline, guttulate. Hyphae monomitic, usually with clamp-connections.

Clavulina cristata (L.) J. Schröt., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1(25–32): 443 (1888) [1889]

Synonyms:
Clavaria coralloides L., Sp. pl. 2: 1182 (1753)
Clavaria coralloides var. alba Bull., Hist. Champ. Fr. (Paris) 1(1): 201 (1791)
Clavaria coralloides var. elegans (Bolton) Purton, Appendix Midl. Fl.: 269 (1821)
Clavaria coralloides var. lappa P. Karst., Bidr. Känn. Finl. Nat. Folk 37: 168 (1882)
Clavaria coralloides var. lutea Bull., Hist. Champ. Fr. (Paris) 1(1): 201 (1791)
Clavaria coralloides-cinerea Bull., Herb. Fr. (Paris) 8: tab. 354 (1788) [1787-88]
Clavaria cristata (Holmsk.) Pers., Syn. meth. fung. (Göttingen) 2: 591 (1801)
Clavaria cristata f. minor Pat., Tab. analyt. Fung. (Paris)(1): 37 (1883)
Clavaria cristata var. ambigua Pass., Erb. critt. Ital., Ser. 2, fasc.: no. 191 (1885)
Clavaria cristata var. cinerascens Sacc., Michelia 1(no. 5): 540 (1879)
Clavaria cristata var. curta Jungh., Linnaea 5: 407 (1830)
Clavaria cristata var. fallax Fr., Syst. mycol. (Lundae) 1: 473 (1821)
Clavaria cristata var. fimbriata Fr., Syst. mycol. (Lundae) 1: 473 (1821)
Clavaria cristata var. flexuosa Jungh., Linnaea 5: 407 (1830)
Clavaria cristata var. minor Pat., Tab. analyt. Fung. (Paris)(3): 116 (1884)
Clavaria cristata var. nivea Pers., Syn. meth. fung. (Göttingen) 2: 591 (1801)
Clavaria cristata var. vulgaris Alb. & Schwein., Consp. fung. (Leipzig): 287 (1805)
Clavaria elegans Bolton, Hist. fung. Halifax (Huddersfield) 3: 115 (1790) [1789]
Clavaria fimbriata Pers., Neues Mag. Bot. 1: 117 (1794)
Clavaria rugosa var. elegans (Bolton) Pers., Syn. meth. fung. (Göttingen) 2: 595 (1801)

*Clavariella cristata (*Holmsk.) P. Karst., Bidr. Känn. Finl. Nat. Folk 37: 187 (1882)
Clavulina coralloides f. bicolour (Donk) Franchi & M. Marchetti, Boll. Circolo Micologico 'Giovanni Carini' 39: 21 (2000)
Clavulina coralloides f. coriobrunnescens Franchi & M. Marchetti, Index Fungorum 457: 1 (2020)
Clavulina coralloides f. cristata (Holmsk.) Franchi & M. Marchetti, Boll. Circolo Micologico 'Giovanni Carini' 39: 21 (2000)
Clavulina coralloides f. fimbriata (Pers.) Courtec., Docums Mycol. 34(nos 135-136): 49 (2008)
Clavulina coralloides f. griseorosata Franchi & M. Marchetti, Index Fungorum 457: 1 (2020)
Clavulina coralloides f. lutea (Bull.) Franchi & M. Marchetti, Index Fungorum 437: 1 (2020)
Clavulina coralloides f. subrugosa (Corner) Franchi & M. Marchetti, Boll. Circolo Micologico 'Giovanni Carini' 39: 30 (2000)
Clavulina cristata (Holmsk.) J. Schröt., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1(25–32): 442 (1888) [1889]
Clavulina cristata f. bicolour Donk, Meded. Bot. Mus. Herb. Rijks Univ. Utrecht 9: 19 (1933)
Clavulina cristata f. subcinerea Donk, Meded. Bot. Mus. Herb. Rijks Univ. Utrecht 9: 19 (1933)
Clavulina cristata subsp. cinerascens Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 693 (1950)
Clavulina cristata subsp. coralloides Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 692 (1950)
Clavulina cristata subsp. eucristata Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 692 (1950)
Clavulina cristata var. bicolour (Donk) Cetto [as 'bicolar'], Enzyklopädie der Pilze, Band 1: Leistlinge, Korallen, Porlinge, Röhrlinge, Kremplinge u.a. (München): 155 (1987)
Clavulina cristata var. brunneola K.S. Thind & Anand, J. Indian bot. Soc. 35: 327 (1956)
Clavulina cristata var. coralloides Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 693 (1950)
Clavulina cristata var. subrugosa Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 693 (1950)
Clavulina cristata var. zealandica R.H. Petersen, Bull. N.Z. Dept. Sci. Industr. Res., Pl. Dis. Div. 236: 61 (1988)
Ramaria alba (Bull.) Quél., C. r. Assoc. Franç. Avancem. Sci. 22(2): 488 (1894)
Ramaria coralloides (L.) Bourdot, Rev. Sci. Bourb. Centr. Fr. 7: 119-126 (1894)
Ramaria cristata Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 92 (1790)
Stichoramaria cristata (Holmsk.) Ulbr., in Lindau, Krypt.-Fl. Anfäng. (Berlin) 3(Aufl. 1): 83 (1928)

FIGURE 30

Basidiomata 50–60 × 3–4 mm, much branched towards the upper portion, polychotomous, stalk generally distinct, 20 to 30 mm long, branchlets arising from the base, apex acute, glabrous, cylindrical, solid, flexouse, terete in cross section, dirty white to cream, whitish towards the branch apex, turning yellowish with age and brownish on drying, context fleshy, without any distinct odour, no positive reaction in KOH, and Fe_3Cl.

Basidiospores 9–11 × 6–10 µm (Q=1–1.5 µm Q_m=1.19 µm), subglobose to globose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–50 × 5–9 µm, cylindrical, without basal clamp-connection, granulate, bi-sterigmate (up to 8 µm long).

Hymenium up to 100 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 4 to 8 µm wide, septate, bulged at the septal portion, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 28 June 2019, Krishnapriya K., ZGCKP165.

Habitat: On soil, in gregarious clusters.

Comments: The present specimen fits with the description by Corner (1950). Much branched *Clavulina* species, *C. cinerea* resembles the present specimen, but differs by the greyish, sparse branching towards the apex, and by the presence of clamp-connection at the base of the basidia in the former (Corner 1950).

Clavulina ornatipes (Peck) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 333 (1950)

Basionym:
Clavaria ornatipes Peck 1908

Synonyms:
Clavaria ornatipes Peck, Bull. N.Y. St. Mus. 122: 18 (1908)
Lachnocladium ornatipes (Peck) Burt, Ann. Mo. bot. Gdn 9(1): 22 (1922)

FIGURE 31

Basidiomata 50–60 × 4–5 mm, branched, branches erect, branching irregular towards the apex, apex acute, branches pruinose, with distinct stalk, stalk up to 20 mm long, rough, strigose-hispid towards the base, slightly bulbous at the base, solid, ellipsoid in cross section, branches greyish brown, stalk brownish, becoming darker on aging and on bruising, context slightly fleshy, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 8–9 × 7–8 µm (Q=1–1.3 µm, Q_m=1.12 µm), subglobose to globose, uniguttulate, smooth, slightly thick-walled (0.5 µm), apiculus prominent (1 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 28–32 × 7–8 µm, clavate to cylindrical, with basal clamp-connection, septate, guttulate, bi-sterigmate (4 to 6 µm

long), cyanophilic in cotton blue. **Hymenium** up to 40 µm wide. **Subhymenium** up to 50 µm wide. **Context** composed of generative hyphae, 3–8 µm wide, slightly thick-walled (less than 1 µm), bulging at the septal portion (up to 12 µm), hyaline to brownish, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kasaragod District, Edayilakkadu kavu, 01 July 2017; Krishnapriya K., KP63.

Habitat: On soil, solitary.

Comments: Both morphological and molecular (ITS sequence) characteristics confirms the identification of the collection as *C. ornatipes. C. ornatipes* resembles *C. decipiens* in its branching patteren and texture of basidiomata, but differs in the presence of strigose hairs on the stalk of the former (Corner 1950).

Clavulina cinerea (Bull.) J. Schröt., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1(25–32): 443 (1888) [1889]

Basionym:
Clavaria cinerea Bull. 1788

Synonyms:
Clavaria cinerea Bull., Herb. Fr. (Paris) 8: tab. 354 (1788) [1787-88]
Clavaria cinerea f. subcristata Bourdot & Galzin, Hyménomyc. de France (Sceaux): 107 (1928) [1927]
Clavaria cinerea f. sublilascens Bourdot & Galzin, Hyménomyc. de France (Sceaux): 107 (1928) [1927]
Clavaria cinerea var. gracilis Rea, Trans. Br. mycol. Soc. 6(1): 62 (1918) [1917]
Clavaria cinerea var. odourata Bourdot & Galzin, Hyménomyc. de France (Sceaux): 107 (1928) [1927]
Clavaria fuliginea Pers., Mycol. eur. (Erlanga) 1: 166 (1822)
Clavaria grisea Pers., Comm. fung. clav. (Lipsiae): 44 (1797)
Clavaria grisea f. petricola Bourdot & Galzin , Hyménomyc. de France (Sceaux): 108 (1928) [1927]
Clavariella grisea (Pers.) P. Karst., Bidr. Känn. Finl. Nat. Folk 37: 186 (1882)
Clavulina cinerea f. bicolour Donk, Meded. Bot. Mus. Herb. Rijks Univ. Utrecht 9: 19 (1933)
Clavulina cinerea f. subcristata (Bourdot & Galzin) Bon & Courtec., Docums Mycol. 18(no. 69): 37 (1987)
Clavulina cinerea f. sublilascens (Bourdot & Galzin) Bon & Courtec., Docums Mycol. 18(no. 69): 37 (1987)
Clavulina cinerea var. gracilis (Rea) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 309 (1950)
Clavulina reae Olariaga, Mycotaxon 121: 38 (2013) [2012]
Clavulina reae f. subcristata (Bourdot & Galzin) Franchi & M. Marchetti, Index Fungorum 380: 1 (2018)
Clavulina reae f. sublilascens (Bourdot & Galzin) Franchi & M. Marchetti, Index Fungorum 380: 1 (2018)

Corallium cinereum (Bull.) G. Hahn, Pilzsammler, Edn 1: 73 (1883)
Merisma cinereum (Bull.) Spreng., Syst. veg., Edn 16 4(1): 497 (1827)
Ramaria cinerea (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)
Ramaria grisea (Pers.) Bourdot, Rev. Sci. Bourb. Centr. Fr. 7: 119-126 (1894).

FIGURE 32

Basidiomata 60–100 × 8–10 mm, much branched, branching polychotomous, irregular, dichotomous towards the apex, flattened, branches stout, thick, up to 7 mm wide, apex pyxidate, blunt, without distinct stalk, glabrous, ridged, longitudinally grooved, solid, ellipsoid in cross section, purplish white, becoming brownish on drying, context fleshy, brittle, without distinct odour, no reaction in Fe_3Cl and KOH.

Basidiospores 9–10 × 7–8 µm (Q=1.1–1.2 µm Q_m=1.17 µm), subglobose to globose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 45–80 × 7–9 µm, granulate, cylindrical to clavate, with basal-clamp connection, sterigmata 1–2 (up to 5 µm long). **Hymenium** up to 100 µm wide. **Subhymenium** up to 60 µm wide. **Context** composed of generative hyphae, 3–10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Idukki District, Anamudi, 09 September 2021, Krishnapriya K., ZGCKP225.

Habitat: On soil, in gregarious groups.

Comments: The present specimen is similar to *C. coralloides* (L.) J. Schröt. in its basidiomatal morphology. However, *C. coralloides* has a white basidiomata with a yellowish tinge and possess cystidia.

Clavulina livida Shu Z. Yan, G. He & Shuang L. Chen, in He, Chen & Yan, Mycoscience 57(4): 256 (2016)

FIGURE 33

Basidiomata 100–130 × 3–8 mm, simple to once branched, flattened (up to 8 mm wide), rarely branched at the apex in some, glabrous when young, becomes longitudinally grooved with ageing, branch tips subacute to round, narrower towards

the base, cylindrical, terete to ellipsoid in cross section, solid when young, hollow on ageing, pruinose, greyish brown, branch tips darker, no colour change on bruising, context fleshy, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 8–12 × 7–9 µm (Q=1–1.3 µm Qm=1.18 µm), sub globose to globose, agguttulate, smooth, hyaline, slightly thick-walled (0.5 µm), wall blackish, apiculus prominent (up to 1 µm long), inamyloid, cynophilic in cotton blue. **Basidia** 35–55 × 7–9 µm, guttulate, clavate, without basal clamp-connection, septate, bi-sterigmate (up to 9 µm long). **Hymenium** up to 110 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 4–8 µm wide, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimen examined: India, Kerala State, Ernakulam District, Iringol kavu, 17 June 2019, Krishnapriya K., ZGCKP185; Kollam District, Palaruvi water falls, Thenmala, 22 September 2019, Krishnapriya K., ZGCKP187.

Habitat: On soil, in gregarious groups.

Comments: The present specimen resembles *C. amethystinoides* (Peck) Corner and *C. castaneipes* (G.F. Atk.) Corner, but differs by the the lilac basidiomata, ellipsoid basidiospores, smaller basidia (22 × 7–10 µm) of *C. amethystinoides* and pinkish filiform basidiomata and obovate basidiospores of *C. castaneipes* (Corner 1950).

Clavulina floridana (Singer) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 323 (1950)

Basionym:
Clavaria floridana Singer 1945

Synonymy:
Clavaria floridana Singer, Mycologia 37(4): 425 (1945)

FIGURE 34

Basidiomata 40–60 × 2–3 mm, simple, unbranched, cylindrical, solid, terete in cross section, narrower towards the base, pruinose, apex acute to subacute,

yellowish white when young, becoming yellowish brown on ageing, darker on drying, context fleshy, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 9–10 × 8–9 µm (Q=1.1–1.2 µm Q_m=1.13 µm), subglobose to globose, uniguttulate, smooth, hyaline, slightly thick-walled (0.5 µm), wall blackish, apiculus prominent (up to 1 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 40–60 × 7–8 µm, cylindrical to clavate, with basal clamp-connection, bi-sterigmate (up to 9 µm long), septate, inamyloid, cyanophilic in cotton blue. **Hymenium** up to 80 µm wide. **Subhymenium** not distinct. **Context** composed of parallely arranged generstive hyphae, 3–8 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Ammayambalam kaavu, 02 October 2021, Krishnapriya K., KP236.

Habitat: On soil, in gregarious groups.

Comments: The present specimen fits with the description by Petersen (1978). *C. geoglossoides* Corner is similar to the present specimen macroscopically, but differs by the blackish unbranched basidiomata, lacrymoid basidiospores, larger basidia (55–60 × 7–8 µm) and presence of cystidia.

Clavulina rugosa (Bull.) J. Schröt., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1(25–32): 442 (1888) [1889]

Basionym:
Clavaria rugosa Bull. 1790

Synonyms:
Clavaria canaliculata Fr., Observ. mycol. (Havniae) 2: 294 (1818)
Clavaria cornu-alces Batsch, Elench. fung. (Halle): 135 (1783)
Clavaria damicornis Schrank [as 'damaecornis'], Baier. Fl. (München) 2: 666 (1789)
Clavaria grossa Pers., Comm. fung. clav. (Lipsiae): 50 (1797)
Clavaria herveyi Peck, Ann. Rep. Reg. N.Y. St. Mus. 45: 84 (1893) [1891]
Clavaria macrospora Britzelm., Ber. naturw. Ver. Schwaben 29: 287 (1887)
Clavaria rugosa Bull., Herb. Fr. (Paris) 10: tab. 448, fig. 2 (1790)
Clavaria rugosa f. mitruloides Bourdot & Galzin, Hyménomyc. de France (Sceaux): 102 (1928)
Clavaria rugosa var. cornu-alces (Batsch) Pers., Syn. meth. fung. (Göttingen) 2: 595 (1801)
Clavaria rugosa var. damicornis (Schrank) Pers., Syn. meth. fung. (Göttingen) 2: 595 (1801)
Clavaria rugosa var. fuliginea Fr., Hymenomyc. eur. (Upsaliae): 669 (1874)

Clavaria rugosa var. grisea Fr., Syst. mycol. (Lundae) 1: 474 (1821)
Clavaria rugosa var. hercynica Pers., Syn. meth. fung. (Göttingen) 2: 595 (1801)
Clavaria rugosa var. tuberculosa Schumach., Enum. pl. (Kjbenhavn) 2: 400 (1803)
Clavicorona rugosa (Bull.) Corner, Beih. Nova Hedwigia 33: 168 (1970)
Clavicorona rugosa var. olivacea Corner, Beih. Nova Hedwigia 33: 168 (1970)
Clavulina herveyi (Peck) R.H. Petersen, Mycologia 59(1): 42 (1967)
Clavulina rugosa f. fuliginea (Fr.) Franchi & M. Marchetti, Index Fungorum 380: 1 (2018)
Clavulina rugosa var. alcyonaria Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 693 (1950)
Clavulina rugosa var. canaliculata (Fr.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 338 (1950)
Clavulina rugosa var. fuliginea (Fr.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 338 (1950)
Clavulina rugosa var. macrospora (Britzelm.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 693 (1950)
Clavulina rugosa var. olivacea Corner, Beih. Nova Hedwigia 33: 168 (1970)
Clavulina rugosa var. tropica Dogma, Philipp. Agric. 50(8): 774 (1967)
Holocoryne rugosa (Bull.) Bonord., Handb. Allgem. mykol. (Stuttgart): 166 (1851)
Ramaria grossa (Pers.) Quél., Fl. mycol. France (Paris): 464 (1888)
Ramaria rugosa (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)

FIGURE 35

Basidiomata 40–80 × 6–10 mm, simple, flexuose, flattened towards the apex, glabrous, longitudinally rugulose to rugose or wrinkled, solid, terete in cross section, apex clefted in some, not acute, cream to yellowish when young, greyish white ageing, brownish on drying, context fleshy, without any distinct odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 8–12 × 8–10 µm (Q=1–1.5 µm Q_m=1.2 µm), subgobose to globose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–65 × 5–6 µm, clavate, without basal clamp-connection, sterigmata 1 to 2 (up to 10 µm long). **Hymenium** up to 100 µm wide. **Subhymenium** not distinct**. Context** composed of generative hyphae, 4 to 8 µm wide, septate, hyaline, slightly thick-walled (0.5 µm wide), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimen examined: India, Kerala State, Idukki District, Anamudi, 8 November 2017; Krishnapriya K., ZGCKP82.

Habitat: On soil, in gregarious groups.

Comments: Description of the present specimen matches with that of *C. tasmanica. C. tasmanica* differs by its greyish white basidiomata, cylindric basidia, and pyriform basidiospores (7–9 × 6–8 µm).

Clavulina humilis (Cooke) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 327 (1950)

Basionym:
Clavaria humilis Cooke 1890

Synonymy:
Clavaria humilis Cooke, Grevillea 19(no. 89): 2 (1890)

FIGURE 36

Basidiomata 10–20 × 2–3 mm, simple to less branched, glabrous, apex acute, arising from a mycelial patch, cylindrical, solid, terete in cross section, slightly pruinose, white to cream, apex concolourous, brownish on drying, context fleshy, without any odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 8–9 × 6–8 µm (Q=1.1–1.3 µm Q_m=1.14 µm), subglobose to globose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 19–35 × 5–7 µm, guttulate, cylindrical, without basal clamp-connection, sterigmata 1–2 (up to 6 µm long). **Hymenium** up to 60 µm wide. **Sub hymenium** up to 100 µm wide. **Context** composed of generative hyphae, 4 to 10 µm wide, inflated up to 18 µm, septate, slightly constricted at the septa, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kollam District, Thenmala, 22 September 2019, Krishnapriya K., ZGCKP189.

Habitat: On soil, in gregarious clusters among leaf litter.

Comments: *C. ingrata* Corner resembles the present specimen, but differs by the simple basidiomata with strong smell of fenugreek, larger basidioapores (10–12 × 10–11 µm), and secondarily septate basidia.

Genus *Clavaria*

Basidiomata club to cylindrical or coralloid, white, yellow, orange, pink, violet, green, brown, or blackish. Basidia with or without loop-like basal clamp-connection, basidiospores smooth, hyaline, globose to subglobose or ellipsoid. Cystidia rarely present. Hyphae monomitic, lacking clamp-connections.

Clavaria cystidiata Krishnapriya & T. K. A. Kumar, Mycotaxon 136(4): 728 (2022)

FIGURE 37

Basidiomata 50–110 × 2–3 mm, simple, unbranched, cylindrical, solid when young becoming hollow with age, terete in cross section, apex acute, narrower towards base, glabrous, off white to pale yellow when young, becoming yellowish when mature, dark yellow to pale orange towards the apex, context fleshy, with strong garlic odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 7–10 × 5–8 µm (Q=1.1–1.5 µm, Qm=1.2 µm), broadly ellipsoid, with granulate and guttulate contents (mostly single large oil droplet), smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 50–60 × 7–10 µm, aguttulate to multiguttulate, cylindrical to clavate, with basal clamp-connection, sterigmata 1–2 (up to 5 µm long). **Cystidia** abundant, 21–75 × 10–21 µm, versiform (predominantly cylindrical, clavate, lageniform, broadly clavate), many with apical protrusions that are up to 27 µm long, thin-walled, inamyloid, hyaline. **Hymenium** 20 to 30 µm wide. **Subhymenium** 50 to 60 µm wide. **Context** composed of hyphae that are parallely arranged, 3–25 µm wide, inflated, septate, hyaline to pale yellow, thin- to slightly thick-walled (up to 1µm), cyanophilic, inamyloid. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Madappally college campus, 01 August 2017, Krishnapriya K., ZGCKP59.

Habitat: On soil solitary and in gregarious groups, among leaf litter.

Comments: The present specimen was described as a new species from Kerala (Krishnapriya & Kumar 2021). *C. cystidiata* is characterized by its strong garlic odour. The ITS sequence of the present specimen showed identitiy with *C. fuscata* Oudem., *C. foetida* G.F. Atk., *C. redoleoalii* R.H. Petersen, and *C. falcata* Pers., during BLAST search in NCBI (National Center for Biotechnology Information). All of the four *Clavaria* species exhibit garlic odour. Morphologically, *C. fuscata* differs from *C. cystidiata* in having white basidiomata and cystidia. Basal basidial clamp-connections are absent. Basidiomatal colour of *C. foetida* is similar to that of *C. cystidiata*. However, smaller basidiospores (5.4–7.2 × 3.2–4.0 µm), tetra-sterigmate basidia without basal clamp-connection, and the absence of cystidia in *C. foetida* (Petersen 1988) separates the two. *C. redoleoalii* is a garlic-smelling *Clavaria*, having abundant crystalline material in tramal hyphae, with secondary septations and tetra-sterigmate (Petersen 1988). *C. falcata* differs from *C. cystidiata* in having white to cream basidiomata, absence of basidial clamp-connections, presence of four-spored basidia, and absence of cystidia (Coker 1923; Petersen 1988).

A phylogenetic tree (Fig. 38) was constructed using the newly generated ITS sequence and 47 representatives from Clavariaceae family (Table 4), retrieved from GenBank. *C. cystidiata* clustered in a clade with the three garlic-smelling taxa (*C. fuscata, C. redoleoalii, C. falcata*) and three non-garlic-smelling species (C. *greletoides, C. californica, C. tenuipes*) with 85% ML bootstrap support (BS). *C. cystidiata* resolved as sister to *C. fuscata* (50% BS).

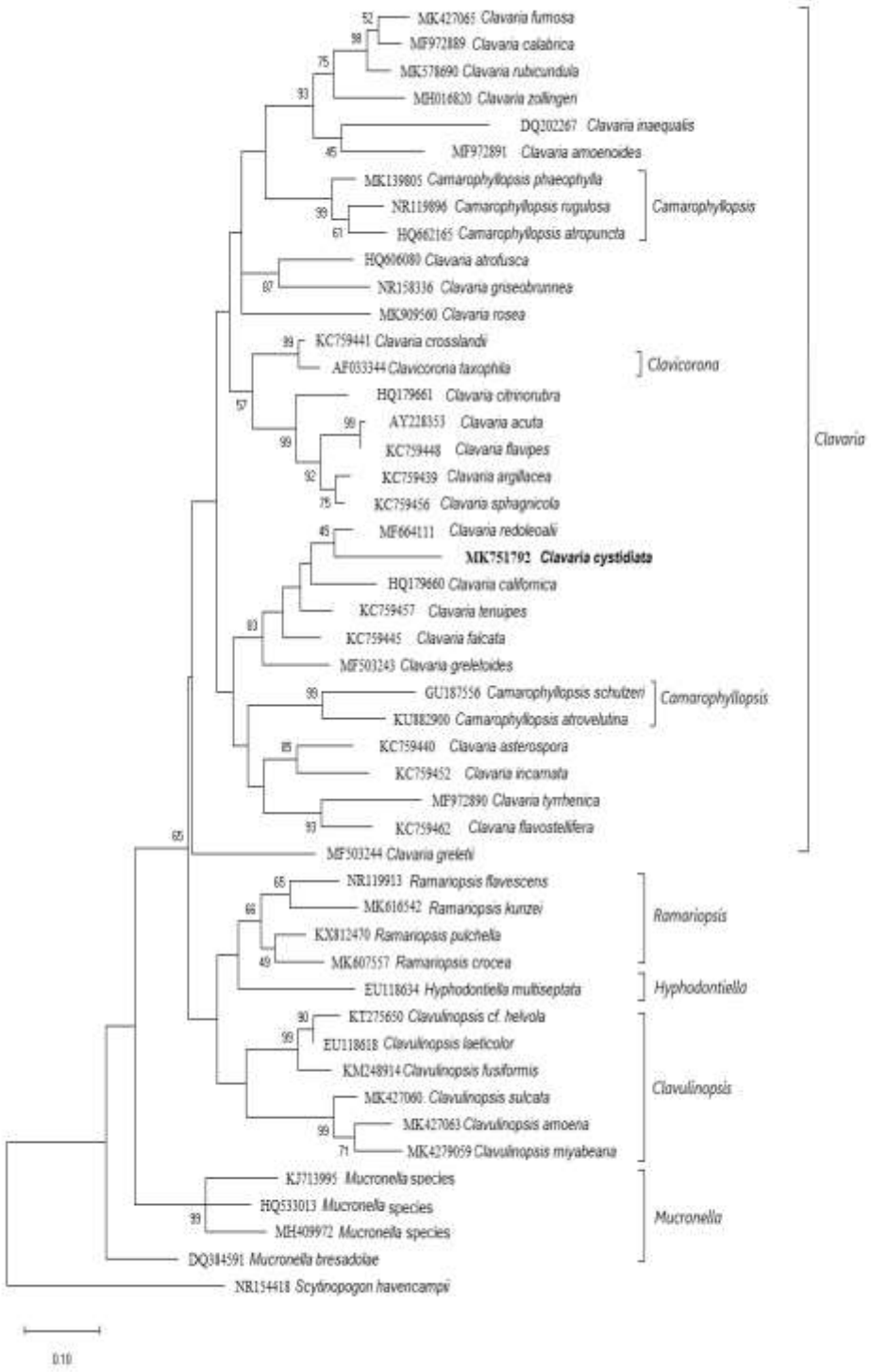


Fig. 38: Maximum likelihood tree showing the phylogenetic placement of *Clavaria cystidiata* (shown in bold). The percentage of trees in which the associated taxa clustered together is shown next to the branches. Boot strap value above 40% are shown.

Clavaria sinensis P. Zhang, in Yan, Wang, Wang, Chen & Zhang, Phytotaxa 477(1): 75 (2020)

FIGURE 39

Basidiomata 60–70 × 5–10 mm, highly branched, main branches irregular, glabrous, dichotomous towards the apex, apex obtuse, without distinct stalk, cylindrical, terete in cross section, solid, cream, with purplish tinge, apex concolourous, context fleshy, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.3 µm), ovoid to ellipsoid, granulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 6–7 µm, granulate, clavate, without basal clamp- connection, ruptures after spore discharge, tetra-sterigmate (3 to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 80 µm wide, **Subhymenium** not distinct. **Context** composed of generative hyphae, 3 to 5 µm wide, septate, interwoven, inflated up to 18 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimens examined: India, Kerala State, Malappuram District, Calicut University campus, 28 June 2019, Krishnapriya ZGCKP119.

Habitat: On soil, in gregarious clusters.

Comments: The present specimen can be easily distinguished from other branched species in the genus *Clavaria* (*C. martini* Corner, *C. pumanquensis* Lazo, *C. zollingeri* Lev., and *C. diverticulata* A.N.M. Furtado & M.A. Neves) by their yellow, cream white to yellowish, deep violet and greenish yellow basidiomata respectively. The present species is very similar to *C. sinensis* described by Yan *et al*. (2020), morphologically.

Clavaria zollingeri Lév., Annls Sci. Nat., Bot., sér. 3 5: 155 (1846)

Synonym:

Clavaria lavandula Peck, Bull. N.Y. St. Mus. 139: 47 (1910)

FIGURE 40

Basidiomata 80–120 × 6–20 mm, highly branched, irregular or polychotomous below, dichotomous above, branches up to 3 mm wide, glabrous, often branched from the base, apex sub-acute to bifurcate, flexuose, terete in cross section, hollow, narrower towards the base, whitish to pale violet when young, distinctly violet when mature, fading with age and on drying, context fleshy, brittle, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.3 µm), ellipsoid, guttulate, smooth, thin-walled, hyaline, apiculus prominent (0.5 to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 45–53 × 6–7 µm, guttulate, clavate, without basal clamp-connection, tetra-sterigmate (3 to 9 µm long), cyanophilic in cotton blue. **Hymenium** up to 100 µm wide. **Subhymenium** up to 30 µm wide. **Context** composed of generative hyphae, 4 to 6 µm wide, septate, inflated up to 18 µm wide, hyaline, thin to slightly thick-walled (0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimens examined: India, Kerala State, Kozhikode District, Peruvannamuzhi, 26 June 2018, Krishnapriya K., ZGCKP105; Malappuram District, Calicut University Campus, 28 June 2018, Krishnapriya K., ZGCKP126; Chiplithodu, Thamarassery, 30 June 2022, Krishnapriya K., ZGCKP256.

Habitat: on soil, in caespitose clusters.

Comments: *C. zollingeri* can be easily identified in the field by its deep violet basidiomata. However, it may be misidentified with *Clavulina amethystina* (Bull.) Donk or *Ramariopsis pulchella* (Boud.) Corner as both possess violet basidiomata. The present specimen differs from *C. amethystina* by its larger basidiomata and tetra-sterigmate basidia, whereas the latter has smaller basidiomata and possess bi-sterigmate basidia. *R. pulchella* differs from the present specimen by its small sized ornamented basidiospores, smaller basidia and the presence of hyphal clamp-connections in the latter (Corner 1950). *C. zollingeri* is reported as a threatened species in Global Fungal Red List Assessments (Mueller *et al*. 2022).

Clavaria xylarioides Petch, Ann. R. bot. Gdns Peradeniya 7(4): 290 (1922)

FIGURE 41

Basidiomata 40–50 × 5–6 mm, simple, cylindrical, narrower towards the base (2–3 mm), wider at the apex, longitudinally grooved, apex obtuse or truncate, solid, terete in cross section, violet-black, context fleshy, without any odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 7–10 × 4–5 µm, (Q=1.4–2.2 µm Q_m=1.7 µm), ellipsoid, aguttulate or uniguttulate, smooth, thin-walled, hyaline, apiculus not prominent (0.5 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–60 × 7–9 µm, clavate, without basal clamp-connection, tetra sterigmate (up to 7 µm long), inamyloid, cyanophilic in cotton blue. **Hymenium** up to 50 µm wide. **Subhymenium** up to 80 µm wide. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, inflated up to 20 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kollam District, Moonnu kandra, Thenmala, 23 September 2019, Krishnapriya K., ZGCKP188.

Habitat: On soil, solitary or in gregarious clusters.

Comments: The present specimen may be confused with *Alloclavaria purpurea* (O.F. Müll.) (Dentinger & D.J. McLaughlin 2007), by its deep purplish to greyish black basidiomata, but clearly differs in the presence of cystidia in the latter.

Clavaria greletii Boud. [as 'greleti'], Bull. Soc. mycol. Fr. 33(1): 13 (1917)

Synonym:

Clavaria greletii var. *grandispora* Corner, Trans. Br. mycol. Soc. 50(1): 37 (1967*)*

FIGURE 42

Basidiomata 30–110 × 3–4 mm, slender, simple, fusiform, glabrous, solid, terete in cross section, apex acute to subacute, glabrous, grey, brownish at the base,

brownish black towards the apex, blackish on drying, context fleshy, fragile, without any odour, no positive reaction in KOH and Fe_3Cl.

Basidiospores 8–10 × 7–8 µm (Q=1.1–1.3 µm Q_m=1.12 µm), globose, granulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–45 × 6–7 µm, guttulate, clavate, with basal clamp-connection, tetra-sterigmate (up to 10 µm long), cyanophilic in cotton blue. **Hymenium** 40 to 50 µm wide, **Subhymenium** 30 to 40 µm wide. **Context** composed of generative hyphae, 3–7 µm wide, inflated (up to 20 µm wide), hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India; Kerala State; Kozhikode District, Madappally college; 01 August 2017; Krishnapriya K., ZGCKP58.

Habitat: On soil, caespitose in gregarious clusters;

Comments: The present specimen fits with the description of *C. greletii* given by Corner (1950). *C. greletii* is similar to *C. greletoides* Arauzo & P. Iglesias by its greyish black basidiomata. However, *C. greletoides* differs microscopically by its reniform to pip shaped and large basidiospores (9–15 × 5–8 µm) (Arauzo & Iglesias 2017).

Clavaria gibbsiae Ramsb., in Gibbs, Contr. Phytogeogr. Arfak. Mount.: 187 (1917)

Synonyms:
Clavaria gibbsiae f. microspora Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 691 (1950)
Clavaria gibbsiae var. megaspora Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 691 (1950)
Clavaria gibbsiae var. tenuis Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 691 (1950)

FIGURE 43

Basidiomata 20–70 × *4*–5 mm, simple, glabrous, almost cylindrical, apex round when young, become acute when mature, solid, terete in cross section, whitish when young, becoming cream, yellowish brown towards the apex, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 7–10 × 6–8 µm (Q=1–1.3 µm Q_m=1.1 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–50 × 6–9 µm, clavate, with loop-like basal clamp-connection, bi-sterigmate (up to 10 µm long). **Hymenium** up to 100 µm wide. **Subhymenium** up to 45 µm wide. **Context** composed of generative hyphae, 3–10 µm wide, septate, inflated up to 20 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., ZGCKP233.

Habitat: On soil, in gregarious groups.

Comments: *C. gibbsiae* fits with the description given by Corner (1950). The present specimen is similar to *C. cystidiata*, but differs by the longer basidiomata with strong garlic odour, and by the presence of cystidia of the latter.

Clavaria luteostirpata S.G.M. Fawc., Proc. Roy. Soc. Victoria 51(2): 267 (1939) [1938]

Synonymy:
Clavulinopsis luteostirpata (S.G.M. Fawc.) Corner, Monograph of *Clavaria a*nd allied Genera, (Annals of Botany Memoirs No. 1): 377 (1950)

FIGURE 44

Basidiomata 50–80 × 2–3 mm, simple, unbranched, cylindrical to flexuose, glabrous, slightly grooved when mature, apex subacute, solid when young, becoming hollow with age, terete in cross section, orange, context fleshy, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 7–8 µm (Q=1–1.3 µm Q_m=1.16 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–50 × 7–8 µm, clavate, with basal clamp-connection, tertra-sterigmate (up to 10 µm long). **Hymenium** up to 80 µm wide. **Subhymenium** up to 30 µm wide. **Context** composed of parallely arranged

generative hyphae, 3–7 µm wide, septate, hyaline thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzi forest, 11 August 2016, Krishnapriya K., ZGCKP93; Thrissur District, Chimmney, 20 July 2021, Krishnapriya K., ZGCKP205.

Habitat: On soil, solitary and in caespitose groups.

Comments: *Clavulinopsis aurantiocinnabaria* resembles the present specimen, but differes by the presence of hyphal clamp-connections in the former genus.

Clavaria rosea Dalman, in Swartz, K. Vetensk-Acad. Nya Handl. 32: 157 (1811)

Synonyms:
Clavaria rosea var. grandispora Corner, Trans. Br. mycol. Soc. 50(1): 41 (1967)
Clavaria rosea var. pallida Corner, Trans. Br. mycol. Soc. 50(1): 41 (1967)
Clavaria rosea var. rubella Pers., Mycol. eur. (Erlanga) 1: 185 (1822)
Clavaria rubella Pers., Comm. fung. clav. (Lipsiae): 81 (1797)

FIGURE 45

Basidiomata 30–50 × 4–5 mm, simple, unbranched, almost cylindrical, apex sub-acute when young, becoming obtuse when mature, glabrous, slightly grooved when mature, solid, terete in cross section, reddish pink, context fleshy, without any odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 6–8 × 3–4 µm (Q=1.5–2 µm Q_m=1.5 µm), ellipsoid, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–45 × 8 µm, guttulate, clavate, without basal clamp-connection, bi-sterigmate (up to 6 µm long). **Hymenium** 20 to 30 µm wide. **Subhymenium** 40 to 50 µm wide. **Context** composed of generative hyphae, 2–4 µm wide, septate, inflated up to 12 µm wide, hyaline to yellowish, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 25 October 2019, Krishnapriya K., ZGCKP197.

Habitat: On soil, solitary and in gregarious groups.

Comments: The present specimen resembles *Clavaria barlae* and *Clavulinopsis corallinorosacea* by its pinkish red basidiomata. But both differs from the present specimen by their branched basidiomata (Corner 1950).

Clavaria vermicularis Batsch, Elench. fung. (Halle): 135 (1783)

Synonyms:
Clavaria cylindrica Bull., Hist. Champ. Fr. (Paris) 1(1): 212 (1791)
Clavaria cylindrica Gray, Nat. Arr. Brit. Pl. (London) 1: 656 (1821)
Clavaria eburnea var. fragilis (Holmsk.) Pers., Syn. meth. fung. (Göttingen) 2: 603 (1801)
Clavaria fragilis var. cylindrica (Bull.) Duby, Bot. Gall., Edn 2 (Paris) 2: 603 (1830)
Clavaria fragilis var. gracilior Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 7 (1790)
Clavaria fragilis var. lutea Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 11 (1790)
Clavaria vermicularis Sw., K. Vetensk-Acad. Nya Handl. 32: 159 (1811)
Clavaria vermicularis var. gracilis Bourdot & Galzin, Hyménomyc. de France (Sceaux): 110 (1928) [1927]
Clavaria vermicularis var. latispora Corner, Proc. Linn. Soc. London 178: 94 (1967)
Clavaria vermicularis var. singaporensis Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 691 (1950)
Clavaria vermicularis var. sphaerospora Bourdot & Galzin, Hyménomyc. de France (Sceaux): 110 (1928) [1927]
Xylaria albicans var. cylindrica (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 511 (1821)

FIGURE 46

Basidiomata 30–60 mm, simple, unbranched, almost cylindrical, flexuose or twisted when mature, narrower towards the base, flattened at the apex, longitudinally grooved, glabrous, terete in cross section, solid when young, becoming hollow when mature, white, pale yellowish on drying, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 4–5 µm (Q=1.4–2 µm Q_m=1.4 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 2 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 45–60 × 6–8 µm, clavate, without basal clamp-connection, tetra-sterigmate (up to 10 µm long). **Hymenium** up to 30 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3–10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Malappuram District, Calicut University Campus, 16 June 2022, Krishnapriya K., ZGCKP254.

Habitat: On soil, in gregarious clusters.

Comments: The description of present specimen fits with the description of *C. vermicularis* by Corner (1950) and Thind (1961). It resembles *C. fragilis* in its whitish basidiomata. But the present specimen differs by the smaller basidiomata, larger basidia and basidiospores, and by its uninflated hyphae (Corner). Another similar species, *C. acuta* differs by its loop-like clamp-connection at the base of basidia (Corner 1950).

Clavaria echinonivosa R.H. Petersen [as '*echino-nivosa*'], Bull. N.Z. Dept. Sci. Industr. Res., Pl. Dis. Div. 236: 22 (1988)

FIGURE 47

Basidiomata 20–30 × 2–4 mm, simple, unbranched, cylindrical, apex round, narrower towards base, glabrous, solid, terete in cross, off white to pale yellowish, becoming brownish on drying, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 5–7 µm (Q=1–1.3 µm Q_m=1.09 µm), subglobose, uniguttulate, echinulate (spines up to 2 µm long), thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 25–28 × 6–7 µm, clavate, without basal clamp- connection, tetra-sterigmate (up to 6 µm long), cyanophilic in cotton blue. **Hymenium** up to 30 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3–5 µm wide, septate, inflated up to 15 µm wide, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Malikkadavu, 18 October 2013, Binusha B., VB15; Pokkunnu, 22 October 2013, Binusha B., VB16.

Habitat: On soil, solitary.

Comments: The present specimen fit with the description of *C. echinonivosa* by Petersen (1988). *C. asterospora* resembles the present specimen by its small, white

basidiomata, but differes by the larger basidiospores 7–10 × 6–8 µm, and presence of basal basidial clamp-connection in it (Corner 1970).

Clavaria citriceps G.F. Atk., Annls mycol. 6(1): 56 (1908)

Synonym:
Clavaria vermiculata var. citriceps (G.F. Atk.) Cejp [as 'citripes'], Mykologia (Prague) 7(2): 112 (1930)

FIGURE 48

Basidiomata 25–30 × 2 mm, simple, unbranched, cylindrical, slightly narrower towards the base and the apex, apex subacute, glabrous, terete in cross section, solid when young, becoming hollow when mature, whitish with a yellow base, context fleshy, without any odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=1.2–1.5 µm Q_m=1.3 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic. **Basidia** 35–40 × 6–7 µm, guttulate, clavate, without basal clamp-connection, sterigmata 1–4 (up to 10 µm long). **Hymenium** up to 40 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3–10 µm wide, septate, inflated (up to 15 µm wide), hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Thiruvananthapuram District, Palode, 01 October 2021, Krishnapriya K., ZGCKP230.

Habitat: On soil, solitary or gregarious, among leaf litter.

Comments: The present collection is similar in appearance with *C. acuta* Sowerby. However, it differs in having larger basidiospores and loop-like clamp-connection at the base of basidia (Corner 1950).

Clavaria macounii Peck, Ann. Rep. Reg. N.Y. St. Mus. 47: 150 (1894)

Synonym:

Clavulinopsis macounii (Peck) Corner [as 'macouni'], Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 378 (1950)

FIGURE 49

Basidiomata 35–40 × 4–5 mm, simple, almost cylindrical, narrower towards base (up to 2 mm), flattened, longitudinally grooved, flexuose, glabrous, ellipsoid in cross section, solid, apex subacute to obtuse, yellowish green, with brownish tinge at apex and base, becoming darker on drying, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 3–4 µm (Q=1.3–1.5 µm Q_m=1.5 µm), ellipsoid, uniguttulate, smooth, thin-walled, hyaline, apiculus not prominent (0.5 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 30–60 × 5–6 µm, clavate, without basal clamp-connection, tetra-sterigmate (up to 4µm long), cyanophilic in cotton blue. **Hymenium** 20–40 µm wide. **Sub hymenium** up to 70 µm wide. **Cortex** composed of generative hyphae, 5 µm wide, inflated up to 18 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India; Kerala State; Kozhikode District, Pokkunu; 18 June 2017; Krishnapriya K., ZGCKP41.

Habitat: On soil, solitary.

Comments: The present specimen fits with the description of *C. macounii* by Corner (1950). *Clavulinopsis citrinoalba* is a greenish yellow species, but differs by its branched basidiomata (Corner 1950).

Clavaria viriditincta Krishnapriya & T. K. A. Kumar *sp. nov.*

FIGURE 50

Basidiomata 30–80 × 3–5 µm, simple, unbranched, cylindrical, solid when young, becoming fistulose with age, terete in cross section, apex acute to subacute, glabrous, deep green, darker at the extreme apex, no colour changes on bruising, context fleshy, without any distinct odour, no colour reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 4–5 µm (Q=1.2–1.7 µm, Q_m=1.4 µm), ellipsoid, guttulate, smooth, thin-walled, hyaline, guttulate, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 7–8 µm, agguttulate, clavate, without basal clamp-connection, tetra-sterigmate (up to 5 µm long). **Hymenium** 20–30 µm wide. **Subhymenium** 40–50 µm wide. **Context** composed of generative hyphae, 4–10 µm wide, inflated up to 20 µm wide, interwoven, septate, with ampulliform septal swellings, hyaline, thick-walled (up to 1 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent

Specimen examined: India, Kerala State, Malappuram District, University of Calicut campus, 16 June 2022, Krishnapriya K., KP247A, KP247B.

Habitat: On soil, caespitose and in gregarious groups.

Comments: The present was distinguished from other *Clavaria* species by its distinct green basidiomata. *Clavaria macounii* differs from the present specimen by its small (20-40 mm long) yellowish green basidiomata, pip shaped basidiospores (4.5–5 × 3–3.8 µm) and, uninflated hyphae without ampullaceous septa. *Clavaria* species with yellowish green basidiomata. *C. macounii* Peck is the closest hit (80 %) in NCBI BLAST search using the newly generated sequences of the present specimen. A data matrix was constructed by combining the newly generated ITS and LSU sequences and ITS and LSU sequences retrieved from GenBank of 35 representative sequences in Clavariaceae (Table 6). *Trechispora havencampii* Desjardin & B.A. Perry (Hydnodontaceae, Trechisporales) wass chosen as the outgroup taxon following Birkebak *et al*. (2013). The ML (Fig. 51) phylogenetic tree was compatible with respect to the majority of clades and taxa. *C. viriditincta* and *C. macounii* forms a sister clade with 71% ML bootstrap support (BS). We propose the present specimen as new to science.

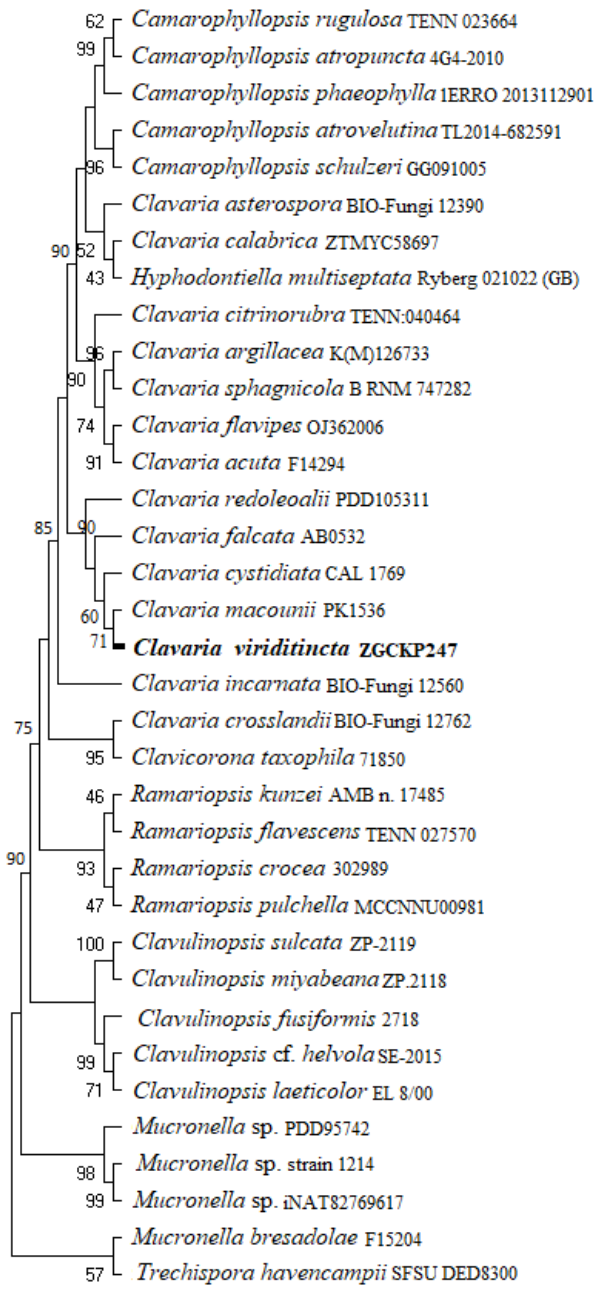


Fig. 51: Maximum Likelihood tree showing the phylogenetic placement of *Clavaria viriditincta*. The percentage of trees in which the associated taxa clustered together is shown next to the branches. Newly generated sequence is in bold.

Clavaria fragilis Holmsk., Beata Ruris Otia Fungis Danicis 1: 7 (1790)

Synonyms:
Clavaria cylindrica Bull., Hist. Champ. Fr. (Paris) 1(1): 212 (1791)
Clavaria cylindrica Gray, Nat. Arr. Brit. Pl. (London) 1: 656 (1821)
Clavaria eburnea var. fragilis (Holmsk.) Pers., Syn. meth. fung. (Göttingen) 2: 603 (1801)
Clavaria fragilis var. cylindrica (Bull.) Duby, Bot. Gall., Edn 2 (Paris) 2: 603 (1830)
Clavaria fragilis var. gracilior Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 7 (1790)
Clavaria fragilis var. lutea Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 11 (1790)
Clavaria vermicularis Sw., K. Vetensk-Acad. Nya Handl. 32: 159 (1811)
Clavaria vermicularis var. gracilis Bourdot & Galzin, Hyménomyc. de France (Sceaux): 110 (1928) [1927]
Clavaria vermicularis var. latispora Corner, Proc. Linn. Soc. London 178: 94 (1967)
Clavaria vermicularis var. singaporensis Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 691 (1950)
Clavaria vermicularis var. sphaerospora Bourdot & Galzin, Hyménomyc. de France (Sceaux): 110 (1928) [1927]
Xylaria albicans var. cylindrica (Bull.) Gray, Nat. Arr. Brit. Pl. (London) 1: 511 (1821)

FIGURE 52

Basidiomata 40–70 × 1–2 mm, simple, unbranched, cylindrical, glabrous, terete in cross section, solid, apex subacute to round, base sterile, arising from a white mycelial patch, whitish, becoming yellowish on drying, context fleshy, fragile, brittle, without distinct odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 4–5 × 3–4 (Q=1.2–1.6 µm Q_m=1.2 µm), broadly ellipsoid, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 7–8 µm, guttulate, broadly clavate, without basal clamp-connection, tetra-sterigmate (up to 8 µm long). **Hymenium** up to 60 µm wide. **Subhymenium** up to 40 µm wide. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, inflated up to 20 µm wide, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kozhikode District, Mukkali, near Silent Valley National Park, 04 July 2019, Krishnapriya ZGCKP172.

Habitat: On soil, gregarious, among leaf litter.

Comments: *C. acuta* with a whitish basidiomata differs from the present specimen by its presence of loop-like clamp-connection at the base of basidia (Corner 1950).

Another *Clavaria* species, *C. vermicularis*, differs by its smaller basidiomata and globose basidiospores (Corner 1950; Thind 1961).

Clavaria fumosa Pers., Observ. mycol. (Lipsiae) 1: 31 (1796)

Synonyms:
Clavaria fragilis var. striata (Pers.) Link, Handbuch zur Erkennung der natuzbarsten und am häufigsten vorkommenden Gewächse 3: 307 (1833)
Clavaria fumosa var. pallida Beeli, Bull. Soc. R. Bot. Belg. 56: 66 (1923)
Clavaria fumosa var. striata (Pers.) Pers., Mycol. eur. (Erlanga) 1: 183 (1822)
Clavaria striata Pers., Comm. fung. clav. (Lipsiae): 75 (1797)

FIGURE 53

Basidiomata 100–110 × 4–6 mm, simple, unbranched, cylindrical, apex subacute to obtuse, narrower towards the base, base sterile, terete in cross section, solid when young, becoming hollow with age, glabrous, longitudinally grooved when mature, cream to pale greyish, becoming brownish on drying, context fleshy, fragile, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–7 × 4–5 µm (Q=1.2–1.7 µm Q_m=1.5 µm), ellipsoid to amygdaliform, agguttulate or guttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–50 × 6–8 µm, clavate, collapsing after spore discharge, without basal clamp-connection, tetra-sterigmate (up to 7 µm long). **Hymenium** up to 80 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, up to 10 µm wide, septate, inflated up to 25 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Palakkad district, Mukkali near Silent Valley National Park, 04 July 2019, Krishnapriya K., ZGCKP175; Kannur district, Aralam, 08 August 2021, krishnapriya K., ZGCKP224.

Habitat: On soil, caespitose in gregarious groups.

Comments: The basidiomatal colour of *C. fumosa* is similar to that of *C. fuscata*, but differs clearly by the strong garlic odour and larger basidopsores (8–10 × 4–5 µm) of the latter.

Genus *Clavulinopsis*

Basidiomata simple or branched, white, yellow, orange, to rarely brown. Basidiospores smooth to rarely verrucose, globose or ellipsoid, basidia with basal clamp-connection. Hyphae monomitic, mostly inflated with clamp-connections.

Clavulinopsis archeri (Berk.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 355 (1950)

Basionym:
Clavaria archeri Berk., in Hooker 1859

Synonymy:
Clavaria archeri Berk., in Hooker, Bot. Antarct. Voy., III, Fl. Tasman. 2: 261 (1859) [1860]

FIGURE 54

Basidiomata 30–60 × 3–4 mm, simple, unbranched, cylindrical, solid when young, fistulose in older basidiomata, terete in cross section, narrower towards the base (2 mm), apex subacute, glabrous, slightly ridged on ageing, orange, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidospores 7–8 × 5–6 (Q=1–1.3 µm Q_m=1.09 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 2 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–45 × 7–8 µm, guttulate, clavate, without basal clamp-connection, bi-sterigmate (up to 5 µm long). **Hymenium** up to 50 µm wide. **Subhymenium** up to 25 µm wide**. Context** composed of parallely arranged generative hyphae, 5–10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 08 August 2021, Krishnapriya K., ZGCKP222.

Habitata: On soil, in gregarious clusteres.

Comments: The present specimen fits with the description by Corner (1950). *C. archeri* may get confused with *C. aurantiocinnabarina* by its orange coloured

basidiomata, but differs in much larger basidiopsores, bisterigmate basidia, and hyphae without inflation (Corner 1950).

Clavulinopsis semivestita (Berk. & Broome) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 387 (1950)

Basionym:
Clavaria semivestita Berk. & Broome 1873

Synonymy:
Clavaria semivestita Berk. & Broome, J. Linn. Soc., Bot. 14(no. 74): 75 (1873) [1875]

FIGURE 55

Basidiomata 60–70 × 4–5 mm, branched, polychotomous below, dichotomous upwards, terminal branches elongate, apex subacute to obtuse, with a distinct stalk, stalk up to 30 mm long, grooved, glabrous, slightly tomentose at the base, solid, terete in cross section, cream, with a pale brownish tinge towards the base, becoming brownish on drying, context fleshy, brittle, with a fungoid odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=1–1.5 µm Q_m=1.2 µm), subglobose to globose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–50 × 6–8 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 7 µm long). **Hymenium** up to 30 µm wide. **Subhymenium** up to 70 µm wide. **Context** composed of generative hyphae, 3–10 µm wide, inflated up to 15 µm wide, septate, hyaline, thin to slightly thick-walled (0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 07 August 2021, Krishnapriya K., ZGCKP221.

Habitat: On soil, in gregarious groups.

Comments: *C. fruticula* resembles the present specimen by its whitish branched basidiomata, but differs by its smaller basidiomata (up to 20 mm long) and smaller (4–5 × 2.5–3.5 µm), pip-shaped basidiospores (Corner 1950).

Clavulinopsis subarctica (Pilát) Jülich, Int. J. Mycol. Lichenol. 2(1): 121 (1985)

Basionym:
Ramariopsis subarctica Pilát 1971

Synonym:
Ramariopsis subarctica Pilát, Česká Mykol. 25(1): 10 (1971)

FIGURE 56

Basidiomata 70 × 5 mm, branched, branches crowded, irregular, dichotomous upwards, glabrous, slightly ridged on aging, apex subacute to blunt, fistulose, ellipsoid in cross section, slightly tomentose at the base, cream, with a pale brownish tinge on ageing, brown on drying, context fleshy, fragile and brittle, with a fungoid odour, no reaction in Fe_3Cl and KOH.

Basidiospores 5–7 × 4–5 µm (Q=1–1.5 µm Q_m=1.2 µm), subglobose to globose, granulate, verrucose, thin-walled, hyaline, apiculus not prominent (up to 0.5 µm), inamyloid, cyanophilic in cotton blue**. Basidia** 30–40 × 10–11 µm, guttulate, clavate to broadly clavate, without basal clamp-connection, tetra-sterigmate (up to 5 µm long), cyanophilic in cotton blue. **Hymenium** 30 to 40 µm wide, **Subhymenium** not distinct. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 25 October 2019, Krishnapriya K., ZGCKP199.

Habitata: On soil, gregarious, among leaf litter.

Comments: The present specimen fits with the description by Shiryaev *et al*. (2017). *R. kunzei* is morphologically similar to the present collection, but differs in the

presence of basal basidial clamp-connection and ellipsoid basidiospores in the former (Corner 1950).

Clavulinopsis rufipes (G.F. Atk.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 386 (1950)

Basionym:
Clavaria rufipes G.F. Atk. 1908

Synonyms:
Clavaria microspora Joss., Bull. trimest. Soc. mycol. Fr. 64(1-2): 31 (1948)
Clavaria rufipes G.F. Atk., Annls mycol. 6(1): 57 (1908)
Clavulinopsis microspora (Joss.) Corner, Bull. trimest. Soc. mycol. Fr. 64(1-2): 29 (1948)
Ramariopsis rufipes (G.F. Atk.) R.H. Petersen, Bull. Torrey bot. Club 91(4): 274 (1964)

FIGURE 57

Basidiomata 50 × 2 mm, branched, branching irregular, elongate, apex subacute, glabrous, with a distinct stalk, up to 20 mm long, pruinose at base, solid, ellipsoid in cross section, yellowish, cream towards the apex, becoming brownish on drying, and reddish on bruising, context fleshy, without any distinct odour, no positive reaction in Fe_3Cl.

Basidiospores 4–5 × 3–4 µm (Q=1.2–1.6 µm Q_m=1.2 µm), ellipsoid, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 23–25 × 4–5 µm, clavate, without basal clamp-connection, bi-sterigmate–4 (up to 6 µm long). **Hymenium** up to 30 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3–8 µm wide, septate, hyaline, thick-walled (up to 1 µm), inamyloid, cyanophilic in cotton blue. Hypahl clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Janaki forest, 02 October 2019, Krishnapriya K., ZGCKP192.

Habitat: On soil, solitary among leaf litter.

Comments: *C. fruticola* resembles the present specimen, but differs by the pip shaped basidiopsores and hyphae with constricted septa. No colour change is observed on bruising (Corner 1950).

Clavulinopsis arenicola Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 694 (1950).

FIGURE 58

Basidiomata 80–100 × 3–5 mm, simple, unbranched, cylindrical when young, becomes flattened on ageing, glabrous, grooved when mature, apex round to obtuse, solid when young, becoming hollow on ageing, ellipsoid in cross section, cream, brownish at the base, context fleshy, brittle, with a fungioid odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–6 × 4–5 µm (Q=1.2–1.7 µm Q_m=1.5 µm), subglobose to globose, aguttulate or uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–46 × 5–6 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 12 µm long), cyanophilic in cotton blue. **Hymenium** up to 40 µm wide, **Subhymenium** up to 20 µm wide. **Context** composed of generative hyphae, 5 to 10 µm wide, septate, interwoven, subhymenial hyphae 2–3 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Malappuram District, Calicut University campus, 20 September 2017, Krishnapriya K., ZGCKP70; Peruvannamuzhi forest, 11 August 2016, Krishnapriya K., ZGCKP91.

Habitat: on soil, in caespitose clusters.

Comments: Characteres of the present specimen fits with those described by (Corner 1950). *C. brevipes* resembles the present specimen, but differs by its smaller basidiomata (up to 40 mm long), absence of basal basidial clamp-connection, and inflated hyphae (Corner 1950).

Clavulinopsis brevipes Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 694 (1950)

Synonymy:

Clavulinopsis brevipes var. termitarii Corner, Proc. Linn. Soc. London 178: 94 (1967)

FIGURE 59

Basidiomata 30–50 × 2–3 mm, simple, unbranched, cylindrical, glabrous, apex sub-acute, narrower towards the base (1–2 mm), slightly pruinose, terete in cross section, solid when young, becoming hollow with age, cream, yellowish at base, context fragile, brittle, without distinct odour, no positive reaction in Fe_3Cl, and KOH.

Basidiospores 6–7 × 5–6 µm (Q=1–1.2 µm Q_m=1.03 µm), subglobose to globose, aguttulate to uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–65 × 6–8 µm, guttulate, clavate, without basal clamp-connection, tetra-sterigmate (up to 13 µm long), cyanophilic in cotton blue. **Hymenium** up to 100 µm wide. **Subhymenium** up to 150 µm wide. **Context** composed of generative hyphae, 4–10 µm wide, septate, inflated up to 17 µm wide, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Malappuram District, Calicut University campus, 28 June 2018, Krishnapriya K., ZGCKP124.

Habitat: on soil, in gregarious groups.

Comments: *Clavaria tenuipes* resembles the present specimen by its smaller whitish basidiomata, but differs by the presence of loop-like clamp-connection at the base of basidia and larger, ellipsoid basidiospores (7–12 × 4–5 µm) (Corner 1950).

Clavulinopsis sulcata Overeem, Bull. Jard. bot. Buitenz, 3 Sér. 5: 279 (1923)

Synonyms:

Clavaria miniata Berk., London J. Bot. 2: 416 bis (1843)
Clavaria phoenicea var. *ealaensis* Beeli, Bull. Soc. R. Bot. Belg. 58: 209 (1926)
Clavaria sulcata (Overeem) R.H. Petersen, Mycologia 70(3): 667 (1978)
Clavulinopsis miniata Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 378 (1950)

Clavulinopsis miniata var. *ealaensis* (Beeli) Corner, Bull. Jard. bot. État Brux. 36(3): 258 *(1966)*
Clavulinopsis miniata var. *rosacea* Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 380 (1950)
Clavulinopsis miniata var. *sanguinea* Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 694 (1950)

FIGURE 60

Basidiomata 60–70 × 5–6 mm, simple, unbranched, in caespitose cluster, cylindrical to flexuose, becoming flattened on ageing, glabrous, longitudinally grooved with age, apex subacute to obtuse, hollow, terete in cross section, ellipsoid when mature, reddish-orange, becoming brownish on drying, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 5–6 µm, (Q=1–1.5 µm Q_m=1.2 µm), subglobose to globose, agguttulate or uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 50–80 × 6–7 µm, clavate, with basal clamp-connection, collapsing after spore discharge, tetra-sterigmate (up to 10 µm long), cyanophilic in cotton blue. **Hymenium** up to 80 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3 to 10 µm wide, septate, inflated up to 15 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp connections present.

Specimens examined: India, Kerala State, Malappuram District, Calicut University campus, 28 June 2018, Krishnapriya K., ZGCKP125; Kozhikode District, Thamarassery, 24 June 2022, Krishnapriya K., ZGCKP252.

Habitat: On soil, in caespitose clusters.

Comments: *C. aurantiocinnabarina* resembles the present specimen macroscopically by it orangish basidiomata. However, *C. aurantiocinnabarina* differes by the larger basidiomata, basidia remaining intact after spore discharge, and by the presence of uninflated hyphae (Corner 1950).

Clavulinopsis aurantiocinnabarina (Schwein.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 350 (1950).

Basinonym: *Clavulinopsis aurantiocinnabarina* (Schwein.) [as '*aurantio-cinnabarina*'] 1832

Synonym:

Clavaria aurantiocinnabarina Schwein. [as '*aurantio-cinnabarina*'], Trans. Am. phil. Soc., New Series 4(2): 183(1832) [1834]

FIGURE 61

Basidiomata 40–130 × 3–5 mm, simple, unbranched, flexuous, narrowly grooved from base to apex, round when young, becoming ellipsoid in cross section, solid, apex acute to sub-acute, glabrous, bright orange, becoming pale orangish brown on drying, context fleshy, brittle, with a fungoid odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 4–7 × 3–5 µm, (Q=1–1.5 µm Q_m=1.2 µm), globose to subglobose, agguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–50 × 7–6 µm, clavate, with basal clamp-connection, bi-sterigmate–4 (up to 10 µm long), cyanophilic in cotton blue. **Hymenium** 75 to 120 µm wide, **Subhymenium** 10–13µm wide. **Context** composed of generative hyphae, 3–10 µm wide, septate, interwoven, hyaline, thin to slightly thick- walled (0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimens examined: India. Kerala State: Kozhikode district, Peruvannamuzhi forest, 24 June 2017, Krishnapriya K., ZGCKP2, ZGCKP6; 10 July 2017, Kodenjeri, Krishnapriya K., ZGCKP51; 26 June 2018, Krishnapriya K., ZGCKP106; Chelappram, 29 June 2013, Binusha B., VB7; Malappuram District, Calicut University Campus, 28 June 2018, Krishnapriya K., ZGCKP 128; Kozhikode district, Chelappram, 29 June 2013, Binusha B., VB6.

Habitat: on soil, gregarious in caespitose clusters.

Comments: The present specimen fits with the description by Corner (1950). *C. sulcata* resembles the present specimen by its orangish basidiomata, but differs by its

comparatively smaller basidiomata (60–70 µm wide), ruptured basidia and inflated hyphae.

Clavulinopsis corniculata (Schaeff.) Corner, Monograph of *Clavaria* and allied genera, (Annals of Botany Memoirs No. 1): 362 (1950)

Basionym:

Clavaria corniculata Schaeff. 1774

Synonyms:
Clavaria corniculata Schaeff., Fung. bavar. palat. nasc. (Ratisbonae) 4: 117 (1774)
Clavaria corniculata var. flaccida Krombh., Naturgetr. Abbild. Beschr. Schwämme (Prague) 7: 21, tab. 53:22-23 (1841)
Clavaria corniculata var. pratensis (Pers.) Cotton & Wakefield, Trans. Br. mycol. Soc. 6(2): 182 (1919) [1918]
Clavaria corniculata var. simplex Donk, Meded. Bot. Mus. Herb. Rijks Univ. Utrecht 9: 88 (1933)
Clavaria fastigiata L., Sp. pl. 2: 1183 (1753)
Clavaria muscoides Sowerby, Col. fig. Engl. Fung. Mushr. (London) 2(no. 14): tab. 157 (1799)
Clavaria muscoides Willd., Fl. berol. prodr.: 407 (1787)
Clavaria pratensis Pers., Comm. fung. clav. (Lipsiae): 51 (1797)
Clavulinopsis corniculata f. bispora Corner ex Pilát, Sb. nár. Mus. Praze 25: fig. 18 (1955)
Clavulinopsis corniculata f. brunneipes (Schild) Franchi & M. Marchetti, Index Fungorum 437: 1 (2020)
Clavulinopsis corniculata f. compacta M.P. Christ., Friesia 8(2): 141 (1968) [1967]
Clavulinopsis corniculata f. simplex (Donk) Lécuru, in Lécuru, Courtecuisse & Moreau, Index Fungorum 384: 1 (2019)
Clavulinopsis corniculata var. brunneipes Schild, Fungorum Rariorum Icones Colouratae 5: 31 (1971)
Clavulinopsis corniculata var. grandis S.S. Rattan & Khurana, Biblthca Mycol. 66: 43 (1978)
Corallium pratense (Pers.) G. Hahn, Pilzsammler, Edn 1: 73 (1883)
Donkella corniculata (Schaeff.) Doty, Lloydia 13: 14 (1950)
Merisma corniculatum (Schaeff.) Spreng., Syst. veg., Edn 16 4(1): 495 (1827)
Merisma pratense (Pers.) Spreng., Syst. veg., Edn 16 4(1): 497 (1827)
Ramaria corniculata (Schaeff.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)
Ramaria corniculata var. alba Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)
Ramaria fastigiata (L.) Holmsk., Beata Ruris Otia FUNGIS DANICIS 1: 90, tab. 23 (1790)
Ramaria pratensis (Pers.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)
Ramariopsis corniculata (Schaeff.) R.H. Petersen, Mycologia 70(3): 668 (1978)
Ramariopsis corniculata var. simplex (Donk) R.H. Petersen, Sydowia 32(1-6): 217 (1980) [1979]

FIGURE 62

Basidiomata 50 × 5 mm, branched, polychotomous below, dichotomous upwards, cylindrical, slightly tomentose at base, glabrous upwards, apex bifurcate, without distinct stalk, solid, terete in cross section, yellow, whitish at the apex, brownish on drying, context fleshy, brittle, without distinct odour, no reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 4–5 µm, (Q=1–1.5 µm Q_m=1.2 µm), subglobose to globose, uniguttulate, smooth, slightly thick-walled (0.5 µm), hyaline, apiculus prominent (up to 2 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–60 × 7–8 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 12 µm long). **Hymenium** up to 100 µm wide. **Subhymenium** up to 40 µm wide. **Cortex** composed generative hyphae, 3–8 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 07 August 2021, Krishnapriya K., ZGCKP214.

Habitat: On soil, solitary, among leaf litter.

Comments: *C. subflava* and *C. tenella* resemble the present specimen by their branched basidiomata. *C. subflava* differs by its whitish to pale yellowish basidiomata and ellipsoid basidiospores (Corner 1950). *C. tenella* can be distinguished by its greyish ochre basidiomata and ovoid basidiospores (Corner 1950).

Clavulinopsis umbrinella (Sacc.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 393 (1950)

Basionym:
Clavaria umbrinella Sacc. 1888

Synonymy:
Clavaria cinereoides G.F. Atk., Annls mycol. 7(4): 367 (1909)
Clavaria umbrina Berk., Outl. Brit. Fung. (London): 279 (1860)
Clavaria umbrinella Sacc., Syll. fung. (Abellini) 6: 695 (1888)
Clavulinopsis cinereoides (G.F. Atk.) Corner [as 'cineroides'], Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 360 (1950)
Ramariopsis umbrinella (Sacc.) R.H. Petersen, Mycologia 70(3): 668 (1978)

FIGURE 63

Basidiomata 70–80 × 5–7 mm, branched, polychotomous below, dichotomous upwards, cylindrical, branches up to 6 mm wide, apex bifurcate to pyxidate, obtuse, with distinct stalk, up to 30 mm long, glabrous, terete in cross section, solid, yellowish brown, becoming brownish with age, apex concolourous with branches, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl.

Basidiospores 6–7 × 5–6 µm, (Q=1–1.5 µm Q_m=1.2 µm), subglobose to globose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–60 × 8–9 µm, guttulate, clavate, with long narrow base, with basal clamp-connection, tetra-sterigmate (up to 10 µm long). **Hymenium** up to 70 µm wide. **Subhymenium** up to 120 µm wide. **Context** composed of generative hyphae, 3–8 µm wide, septate, hyaline, thin to slightly thick-walled (up to 0.5µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 07 August 2021, Krishnapriya K., ZGCKP217.

Habitat: On soil, in gregarious groups, among leaf litter.

Comments: *C. fleischeriana* shows resemblance with the present specimen by its branched basidomata, but clearly differs by the pale yellowish coloured basidiomata and smaller basidopsores (4–4.5 × 3.5–4 µm) (Corner 1950).

Clavulinopsis helvola (Pers.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 372 (1950)

Basionym:

Clavaria helvola Pers. [as 'helveola'] 1797

Synonymy:

Clavaria angustata Pers., Comm. fung. clav. (Lipsiae): 72 (1797)
Clavaria dissipabilis Britzelm., Ber. naturhist. Augsburg 29: 289 (1888)
Clavaria echinospora Boud. & Pat., J. Bot., Paris 2: 341 (1888)
Clavaria flammans Berk., J. Linn. Soc., Bot. 14(no. 77): 350 (1874) [1875]
Clavaria geoglossoides Boud. & Pat., Bull. Soc. mycol. Fr. 8(2): 42 (1892)
Clavaria helvola Pers. [as 'helveola'], Comm. fung. clav. (Lipsiae): 69 (1797)
Clavaria helvola subsp. sylvatica (Pers.) Pers., Mycol. eur. (Erlanga) 1: 182 (1822)
Clavaria helvola var. angustata (Pers.) Pers., Mycol. eur. (Erlanga) 1: 181 (1822)
Clavaria helvola var. aurantia Pers., Mycol. eur. (Erlanga) 1: 182 (1822)
Clavaria helvola var. dispar Pers., Mycol. eur. (Erlanga) 1: 181 (1822)
Clavaria helvola var. teres (Baumg.) Pers., Syn. meth. fung. (Göttingen) 2: 598 (1801)
Clavaria inaequalis var. angustata (Pers.) Fr., Elench. fung. (Greifswald) 1: 232 (1828)
Clavaria inaequalis var. helvola (Pers.) Fr., Elench. fung. (Greifswald) 1: 232 (1828)
Clavaria similis Boud. & Pat., J. Bot., Paris 2: 446 (1888)
Clavaria sylvatica Pers., Comm. fung. clav. (Lipsiae): 73 (1797)
Clavaria teres Baumg., Fl. Lips.: 653 (1790)
Clavulinopsis helvola f. geoglossoides (Boud. & Pat.) Lécuru, in Lécuru, Courtecuisse & Moreau, Index Fungorum 384: 1 (2019)

Clavulinopsis helvola var. geoglossoides Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 694 (1950)
Donkella helvola (Pers.) Malysheva & Zmitr., Nov. sist. Niz. Rast. 40: 150 (2006)
Ramariopsis helvola (Pers.) R.H. Petersen, Mycologia 70(3): 668 (1978)

FIGURE 64

Basidiomata 20–40 × 3–4 mm, simple, unbranched, cylindrical, glabrous, grooved when mature, narrower towards the base and apex, apex subacute, solid, ellipsoid in cross section, bright yellow, apex concolourous, context fleshy, brittle, without any odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 5–6 µm (Q=1–1.2 µm Q_m=1.1 µm), subglobose to amygdaliform, uniguttulate, verrucose to echinulate, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–45 × 6–8 µm, guttulate, clavate, with basal clamp-connection, bi-sterigmate–4 (up to 5 µm long). **Hymenium** up to 50 µm wide. **Subhymenium** up to 30 µm wide. **Context** composed of generative hyphae, 5–10 µm wide, septate, interwoven, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Idukki District, Anamudi, 10 September 2021, Krishnapriya K., ZGCKP227.

Habitat: On soil, in caespitose clusters.

Comments: Corner (1950) did not mention the presence of clamp-connection at the base of basidia in *C. helvola*, whereas Petersen (1968) observed basidial clamp-connection. In the present specimen basal basidial clamp-connection is observed. *C. luteoochracea* resembles the present specimen by its ornamented basidiospores, but differs by its yellowish brown basidiomata and smaller basidiospores (3.5–5 × 2.5–4 µm).

Clavulinopsis spathuliformis (Bres.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 388 (1950)

Basionym:
Clavaria spathuliformis Bres., in Saccardo 1891

Synonymy:

Clavaria spathuliformis Bres., in Saccardo, Syll. fung. (Abellini) 9: 250 (1891)

FIGURE 65

Basidiomata 20–30 × 3–5 mm, simple, unbranched, almost cylindrical, becoming spathulate with age, broader towards the apex, apex obtuse to spathulate, glabrous, solid, terete when young becoming ellipsoid when mature in cross section, yellow, darker at the extreme apex, becoming brownish on drying, context fleshy, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 7–9 × 5–6 µm, (Q=1–1.3 µm Q_m=1.09 µm), ellipsoid to subglobose, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (2 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–55 × 6–7 µm, clavate, with basal clamp-connection, tetra-sterigmate (6 to 8 µm long), cyanophilic in cotton blue. **Hymenium** up to 70 µm wide, **Subhymenium** up to 60 µm wide. **Context** composed of generative hyphae, 3 to 8 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Malappuram District, Nilambur Teak Museum, 03 July 2018, Krishnapriya K., ZGCKP137; Kozhikode District, Thamarassery, 19 June 2022, Krishnapriya K., ZGCKP253.

Habitat: on soil, solitary, gregarious.

Comments: The present specimen fits with the description given by Corner (1950). *C. amoena* resembles the present specimen, but differs in having smaller basidiospores (5–7 × 4–6 µm) and inflated hyphae (Corner 1950). *C. helvola* may be misidentified as *C. spathuliformis* by its small and yellowish basidiomata, but the spathulate apex and smooth bsaidiospores distinguish it from the latter (Corner 1950).

Clavulinopsis ochracea Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 695 (1950)

FIGURE 66

Basidiomata 10–30 × 3 mm, small, simple, unbranched, cylindrical, fistulose, terete in cross section, glabrous, apex subacute, yellow, apex concolourous, context fleshy, brittle, without any odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 5–6 µm, (Q=1–1.3 µm Q_m=1.09 µm), subglobose, aguttulate or uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 45–54 × 7–10 µm, guttulate or aguttulate, clavate, with basal clamp-connection, sterigma 2–4 (up to 7 µm long. **Hymenium** up to 80 µm wide. **Subhymenium** up to 60 µm wide. **Context** composed of generative hyphae, 4–10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 25 October 2019, Krishnapriya K., ZGCKP200.

Habitat: On soil, in caespitose clusteres.

Comments: The present specimen resembles *C. citrinoalba* by its small yellowish basidiomata, but differs from that species by its bifurcate apex (Corner 1950). *C. helvola* differs from the present specimen by the presence of ornamented basidiospores (Corner 1950).

Clavulinopsis appalachiensis (Coker) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 355 (1950)

Basinonym:

Clavaria appalachiensis (Coker) 1923

Synonym: *Clavaria appalachiensis* Coker, The Clavarias of the United States and Canada: 53 (1923)

FIGURE 67

Basidiomata 50–110 × 3–5 mm, simple, unbranched, cylindrical, narrowly grooved when mature, glabrous, apex sub-acute to obtuse, solid when young, becoming hollow when mature, terete in cross section, yellowish to cream, pale towards the base, becoming paler with ageing, brownish on drying, context fleshy, fragile, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 5–7 µm (Q=1–1.2 µm Q_m=1.3 µm), globose to subglobose, aguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1µm

long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–60 × 7–6 µm, clavate, with basal clamp-connection, bi-sterigmate–4 (up to 12 µm long), cyanophilic in cotton blue. **Hymenium** up to 70 µm wide, **Subhymenium** up to 35 µm wide. **Context** composed of generative hyphae, 3 to 4 µm wide, interwoven, septate, inflated up to 15 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Kozhikode District, Peruvannamuzhi, 24June 2017, Krishnapriya K., ZGCKP3; 11 August 2017, Krishnapriya K., ZGCKP92; Malappuram District, Calicut University Campus, 28 June 2018, Krishnapriya K., ZGCKP 122; Kannur district, Aralam, 28 June 2019, Krishnapriya K., ZGCKP157.

Habitat: On soil, in caespitose clusters.

Comments: The present specimen matches with the description of *C. appalachiensis* given by Corner (1950). The present specimen is similar to *Clavaria luteostirpata* (S.G.M. Fawc.) Corner in appearance, but differs from the yellowish orange basidiomata and larger basidiospores (8–10 × 7–9 µm) of the latter.

Clavulinopsis fusiformis (Sowerby) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 367 (1950)

Basionym:
Clavaria fusiformis Sowerby 1799

Synonyms:
Clavaria ceranoides Pers., Syn. meth. fung. (Göttingen) 2: 594 (1801)
Clavaria compressa Schwein., Trans. Am. phil. Soc., New Series 4(2): 182 (1832) [1834]
Clavaria fusiformis Sowerby, Col. fig. Engl. Fung. Mushr. (London) 2(no. 18): tab. 234 (1799)
Clavaria fusiformis f. aurantiaca S. Imai, Trans. Sapporo nat. Hist. Soc. 16: 215 (1941)
Clavaria fusiformis var. ceranoides W.G. Sm., Syn. Brit. Basidiomyc.: 434 (1908)
Clavaria fusiformis var. congoensis Beeli, Bull. Soc. R. Bot. Belg. 58: 209 (1926)
Clavaria inaequalis var. fusiformis (Sowerby) Fr., Elench. fung. (Greifswald) 1: 231 (1828)
Clavaria platyclada Peck, Bull. Torrey bot. Club 23(10): 419 (1896)
Clavulinopsis fusiformis var. bispora K.S. Thind & Sharda, Research Bulletin of the Panjab University, Science 33(3-4): 139 (1982)
Ramaria ceranoides (Pers.) Gray, Nat. Arr. Brit. Pl. (London) 1: 655 (1821)
Ramariopsis fusiformis (Sowerby) R.H. Petersen, Mycologia 70(3): 668 (1978)

FIGURE 68

Basidiomata 80–100 × 4–5 mm, simple, unbranched, cylindrical, becoming flattened with age, glabrous, solid when young, becoming hollow when mature, terete in cross section, apex sub-acute to acute, pruinose, yellow, becoming brownish yellow on drying, context fleshy, brittle, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–8 × 6–7 µm (Q=1–1.2 µm Q_m=1.44 µm), subglobose, aguttulate to guttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–50 × 5–8 µm, cylindrical to clavate, with basal clamp-connection, tetra-sterigmate (4 to 11 µm long), cyanophilic in cotton blue. **Hymenium** 80 µm wide. **Subhymenium** not distinct. **Context** composed of generative hyphae, 3 to 10 µm wide, interwoven, septate, inflated up to 12 µm, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections frequent.

Specimens examined: India, Kerala State, Kozhikode District, Peruvannamuzhi, 26 June 2018, Krishnapriya K., ZGCKP109; Kannur District, Aralam, 28 June 2019, Krishnapriya K., ZGCKP159, ZGCKP223; Palakkad district, Parambikulam, 05 June 2022, Krishnapriya K., ZGCKP244.

Habitat: On soil, in gregarious clusters, among leaf litter.

Comments: *C. fusiformis* may get confused with *C. laeticolour* (Berk. & M.A. Curtis) R.H. Petersen. *C. fusiformis* is typically yellow, while *C. laeticolour* is bright orange yellow and turns greenish yellow with KOH (Messuti & Lorenzo 2015). *C. sulcata* differs from *C. fusiformis* by the yellowish white basidiomata, and smaller basidiospores (5–7 × 4–6 µm) without prominent apiculus.

Clavulinopsis spiralis (Jungh.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 388 (1950)

Basinonym:

Clavaria spiralis Jungh. 1838

Synonym:

Clavaria spiralis Jungh., Verh. Batav. Genootsch. Kunst. Wet. 17(2): 32 (1838)

FIGURE 69

Basidiomata 80–100 × 4–5 mm, simple, rarely branched, cylindrical, glabrous, narrower towards the base, wider towards the apex, apex sub-acute to acute, terete when young, becoming ellipsoid on age, solid, longitudinally grooved, yellowish white, yellow towards the base, context fleshy, brittle, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–7 × 4–6 µm, (Q=1–1.2 µm Q_m=1.1 µm), globose to subglobose, uniguttulate, smooth, thin-walled, hyaline, apiculus not prominent (0.5 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–60 × 6–8 µm, clavate, with basal clamp-connection, bi-sterigmate–4, (up to 10 µm long). **Hymenium** 60 to 70 µm wide. **Subhymenium** 70 to 80 µm wide. **Cortex** composed of generative hyphae, 5 to 12 µm wide, septate, narrow hyaphe less than 4 µm wide in the subhymenium, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp- connections present.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzhi, 24 June 2017, Krishnapriya K., ZGCKP8; Malappuram District, Calicut University campus, 28 June 2018, Krishnapriya K., ZGCKP123; Kannur district, Aralam, 29 June 2019, Krishnapriya K., ZGCKP158; Chelappram, Kozhikode district, 07 July 2013, Binusha B., VB6, VB12; Palakkad district, Parambikulam, 05 June 2022, Krishnapriya K., ZGCKP243.

Habitat: On soil, in caespitose clusters.

Comments: The present specimen fits with the desription of *C. spiralis* by Corner (1950). *C. spiralis* is similar to *C. amoena* and *C. fusiformis*. *C. amoena* differs from the present specimen by its yellowish orange basidiomata and larger basidiospores (7.0−9.0 × 7.0−8.5 µm). *C. fusiformis* differs by its yellow basidiomata, and larger basidiospores (6–8 × 6–7 µm) with prominent apiculus (Corner 1950).

Clavulinopsis amoena (Zoll. & Moritzi) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 352 (1950)

Basionym:

Clavaria amoena Zoll. & Moritzi 1844

Synonyms:
Clavaria amoena Zoll. & Moritzi, Natuur-Geneesk. Arch. Ned-Indië 1: 380 (1844)
Clavaria cardinalis Boud. & Pat., J. Bot., Paris 2: 341 (1888)
Clavaria subargillacea S. Ito & S. Imai, Trans. Sapporo nat. Hist. Soc. 15: 55 (1937)
Clavulinopsis aurantiocinnabarina f. amoena (Zoll. & Moritzi) R.H. Petersen, Mycol. Mem. 2: 25 (1968)

FIGURE 70

Basidiomata 50–80 × 4–5 mm, simple, cylindric when young, flattened in some, glabrous, base pruinose, grooved when mature, apex subacute to acute, solid when young, fistulose when mature, terete in cross section, yellowish orange, context fleshy, without any distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 5–7 × 4–6 µm (Q=1–1.2 µm Q_m=1.1 µm), subglobose, aguttulate or uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 40–60 × 7–10 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 8 µm long). **Hymenium** up to 50 µm wide. **Subhymenium** up to 80 µm wide. **Context** composed of generative hyphae, 3–10 µm wide, septate, interwoven, inflated up to 15 µm wide, hyaline, thin- to slightly thick-walled (up to 0.5µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Madappally college campus, 01 August 2017, Krishnapriya ZGCKP59. Malappuram District, Calicut University Campus, 16 June 2022, Krishnapriya K., ZGCKP250.

Habitat: On soil, as a cluster.

Comments: The morphology of the present specimen agrees well with the description by Corner (1950). It shows resemblance with *C. aurantiocinnabarina*, but differs by

the larger and reddish orange basidiomata and uninflated hyphae in the latter (Corner 1950).

Genus *Ramariopsis*

Basidiomata branched, white, yellowish, ochraceous to cinnamon, purple. Basidiospores globose to broadly ellipsoid, verrucose to echinulate, rarely smooth. Basidia clavate, with basal clamp-connection, two to four sterigmata. Hyphae monomitic, generally narrow, thin- or slightly thick-walled, with clamps-connections, and without secondary septations.

Ramariopsis ramarioides R.H. Petersen, Bull. N.Z. Dept. Sci. Industr. Res., Pl. Dis. Div. 236: 138 (1988)

FIGURE 71

Basidiomata 60–70 × 4–5 mm, highly branched, polychotomous below, terminal branching dichotomous, glabrous, pruinose towards the apex of the branches, apex bifurcate, with distinct stalk, up to 20 mm long, solid, cylindrical, terete in cross section, brown with a purplish tinge, with pale brownish stalk, becoming darker on drying, context fleshy, fragile, without distinct odour; no positive reaction in Fe_3Cl and KOH.

Basidiospores 4–5 × 3–4 µm (Q = 1.1–1.4 µm, Q_m = 1.3 µm), ellipsoid, aguttulate, rarely uniguttulate, verruccose, yellowish, slightly thick-walled (0.5 µm), apiculus prominent (up to 1 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 35–45 × 5–6 µm, clavate with basal clamp-connection, tetra-sterigmate (up to 5 µm long). **Hymenium** up to 40 µm wide, **Subhymenium** up to 100 µm wide. **Context** composed of parallely arranged generative hyphae, 4 to 6 µm wide, inflated up to 15 µm wide, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp- connections present.

Specimen examined: India, Kerala State, Kozhikode District, Pokkunnu, 18 July 2017, Krishnapriya K., ZGCKP39; Janakikkadu Forest, 19 July 2017, Krishnapriya K., ZGCKP87. **Habitat:** On soil, in gregarious groups, among leaf litter.

Comments: The characters of the present collections match with the taxonomic description of *R. ramarioides* by Petersen (1988). The present specimen is similar to *R. clavuligera*, but differes by the ochraceous basidiomata, globose basidiospores and smaller basidia in the latter (Corner 1950).

Ramariopsis subtilis (Pers.) R.H. Petersen, Mycologia 70(3): 668 (1978)

Basionym:
Clavaria subtilis Pers. 1797

Synonyms:
Clavaria dichotoma Godey, in Gillet, Hyménomycètes, Fasc. Suppl. (Alençon): 766 (1878)
Clavaria macropus Pers., Comm. fung. clav. (Lipsiae): 51 (1797)
Clavaria subtilis Pers., Comm. fung. clav. (Lipsiae): 51 (1797)
Clavaria subtilis var. macropus (Pers.) G. Winter, Rabenh. Krypt.-Fl., Edn 2 (Leipzig) 1(1): 314 (1881) [1884]
Clavaria subtilis var. tehovensis Velen., Novitates Mycologicae Novissimae: 165 (1939)
Clavulinopsis dichotoma Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 365 (1950)
Clavulinopsis subtilis (Pers.) Corner, Monograph of Clavaria and allied Genera, (Annals of Botany Memoirs No. 1): 391 (1950)
Merisma macropus (Pers.) Spreng., Syst. veg., Edn 16 4(1): 496 (1827)
Merisma subtile (Pers.) Spreng., Syst. veg., Edn 16 4(1): 496 (1827)
Merisma subtile var. delicata J. Becker, Fl. Frankfurt, Zweite Abth. (Frankfurt): 671 (1828)
Ramaria subtilis (Pers.) Quél., Fl. mycol. France (Paris): 463 (1888)
Ramariopsis dichotoma (Corner) R.H. Petersen, Mycologia 70(3): 668 (1978)
Ramariopsis macropus (Pers.) Paechn., in Kreisel, Pilzflora der Deutschen Demokratischen Republik. Basidiomycetes (Gallert-, Hut- und Bauchpilze) (Jena): 207 (1987)

FIGURE 72

Basidiomata 30–40 × 2–3 mm, branched, dichotomous, slightly grooved, cylindrical, apex mostly bifurcate, glabrous, with a distinct stalk, up to 5 mm long, pruinose towards base, solid, terete in cross section, whitish, base brownish, becoming pale brownish with ageing, context fleshy, without distinct odour, no reaction in Fe_3Cl and KOH.

Basidiospores 4–5 × 3–4 µm (Q = 1.1–1.6 µm, Q_m = 1.2 µm), ellipsoid, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 25–35 × 5–6 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 6 µm long), cyanophilic in cotton blue. **Hymenium** up to 45 µm wide, **Subhymenium** up to 30 µm wide. **Context** composed

of generative hyphae, 3 to 10 µm wide, septate, interwoven, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimens examined: India, Kerala State, Malappuram District, Nilambur Teak Museum, 03 July 2018, Krishnapriya K., ZGCKP136

Habitat: on soil, in gregarious clusters.

Comments: The present specimen fits with the species description of *Clavulinopsis subtilis* by Corner (1950). *Clavulinopsis mintula* and *C. puiggerii* show resemblances with the present specimen. *C. mintula* differs by its smaller basidiomata and ornamented basidiospores (Corner 1950). *C. puiggerii* differs by its globose basidiospores (Corner 1950).

Corner (1950) placed this species in the genus *Clavulinopsis* by its smooth basidiospores and presence of basidial and hyphal clamp-connections. However, Petersen (1978) proposed the genus *Ramariopsis* by dividing it into two subgenera. They are *Laevispora*, for species with smooth-spores, and *Ramariopsis*, for species with echinulate spores. Petersen (1978) included *C. subtilis* in the subgenus *Laevispora* as *Ramariopsis subtilis* because of the smooth basidiopsores. To resolve this uncertainity in placement, a BLAST search was conducted using the newly generated ITS sequence, in which *R. subtilis* was found to be the closest hit (95%). A phylogenetic tree (Fig. 73) constructed using the newly generated ITS sequence of the present specimen and 42 representatives from Clavariaceae family, retrieved from GenBank (Table 7). The present specimen positioned in *Ramariopisis* clade, along with other *R. subtilis* species with 96% BS. Thus, we confirmed the placement of the species in the genus *Ramariopsis* as *R. subtilis*.

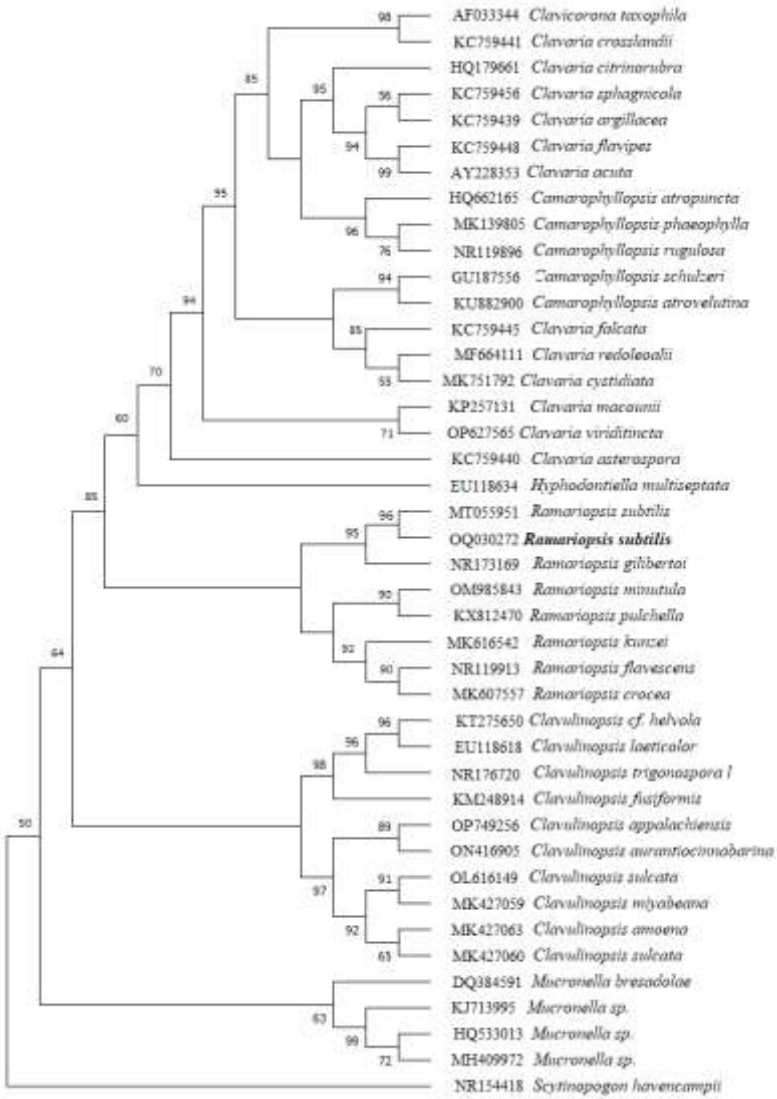


Fig. 73: Maximum Likelihood tree showing the phylogenetic placement of *R. subtilis.* The bootstrap values associated with the branches are shown. The newly generated sequence is in bold.

Ramariopsis clavuligera (R. Heim) Corner Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 638 (1950).

Basinonym:

Clavaria clavuligera R. Heim 1934

Synonyms:

Clavaria clavuligera R. Heim, Mus. barcin. Scient. nat. Op., Ser. Bot.: 46 (1934) *Clavulinopsis clavuligera* (R. Heim) Jülich, Int. J. Mycol. Lichenol. 2(1): 120 (1985)

FIGURE 74

Basidiomata 60–70 × 5–6 mm, main branches irregular, dichotomous upwards, cylindrical, glabrous, slightly pruinose towards the apex, apex acute, bifurcate, with a distinct stalk, up to 25 mm long, arising from a white mycelial patch, terete in cross section, solid, branches ochraceous, stalk brown, becoming darker on drying, context fleshy, fragile, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 6–7 × 5–6 µm (Q=0.9–1.1 µm Q_m=1.2 µm), subglobose to ellipsoid, uniguttulate, verrucose, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. **Basidia** 15–27 × 5–7 µm, broadly cylindrical to obvoid, with basal clamp-connection, sterigmata 2 to 4, (up to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 40 µm wide, **Subhymenium** up to 50 µm wide. **Context** composed of generative hyphae, 3–10 µm wide, interwoven, septate, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzhi; 24 June 2017, Krishnapriya K., ZGCKP7; 26 June 2018, Krishnapriya K., ZGCKP108; Kannur district, Aralam, 28 June 2019, Krishnapriya K., ZGCKP156.

Habitat: On soil, in gregarious clusters, among leaf litter.

Comments: The present specimen fits with the description by Corner (1950). The present specimen resembles with that of *R. lorithamnus*, but can be distinguished by the pip-shaped basidiospores in the latter.

Ramariopsis tenuiramosa Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 700 (1950)

Synonymy:
Clavulinopsis tenuiramosa (Corner) Jülich, Int. J. Mycol. Lichenol. 2(1): 121 (1985)

FIGURE 75

Basidiomata 40–100 × 4–6 mm, branched, branching polychotomous below, dichotomous upwards, slender, with a distinct stalk, up to 40 mm long, glabrous,

tomenstose towards the base, apex bifurcate, terete in cross section, solid, white, with yellowish at the apex, becoming brownish on drying, context fleshy, without distinct odour, no reaction in Fe_3Cl.

Basidiospores 5–6 × 4–5 µm (Q=0.8–1.2 µm Q_m=1 µm), subglobose to globose, agguttulate to uniguttulate, echinulate (0.5 µm), thin-walled, hyaline, apiculus prominent (up to 1 µm), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 5–6 µm, guttulate, clavate, with basal clamp-connection, sterigmata 2 to 4 (up to 5 µm long), cyanophilic in cotton blue. **Hymenium** up to 30 µm wide. **Subhymenium** not distinct. **Cortex** composed of generative hyphae, 3–10 µm wide, septate, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Palakkad District, Parambikulam, 05 June 2022, Krishnapriya K., ZGCKP240.

Habitat: On soil, in gregarious clusters, among leaf litter.

Comments: *R. kunzei* resembles the present specimen, but differs by the whitish basidiomata with concolourous apex, and ellipsoid basidiospores (3–5 × 3–4 µm). *T. angulispora* differs by the ellipsoid angular basidiopsores and smaller basidiomata (Corner 1950).

Ramariopsis kunzei (Fr.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 640 (1950).

Basionym: *Clavaria kunzei* Fr.

Synonyms:

Clavaria asperula G.F. Atk., Annls mycol. 6(1): 54 (1908)
Clavaria asperulans G.F. Atk., Annls mycol. 6(1): 55 (1908)
Clavaria chionea Pers., Mycol. eur. (Erlanga) 1: 167 (1822)
Clavaria elongata Britzelm., Révision des Hyménomycètes de France 1: 221 (1898)
Clavaria favreae (Quél.) Sacc. & Traverso, in Saccardo & Trotter, Syll. fung. (Abellini) 21: 429 (1912)
Clavaria krombholzii Fr., Epicr. syst. mycol. (Upsaliae): 572 (1838) (1836-1838)
Clavaria kunzei Fr., Syst. mycol. (Lundae) 1: 474 (1821)
Clavaria subcaespitosa Peck, Bull. N.Y. St. Mus. 167: 39 (1913) (1914)
Clavaria subcorticalis Schwein., Trans. Am. phil. Soc., New Series 4(2): 182 (1832) [1834]

Clavaria velutina Ellis & Everh., in Ellis, N. Amer. Fung., Ser. 2: no. 2024 (1888)
Clavulina kunzei (Fr.) J. Schröt., in Cohn, Krypt.-Fl. Schlesien (Breslau) 3.1(25–32): 442 (1888) (1889)
Clavulinopsis kunzei (Fr.) Jülich, Int. J. Mycol. Lichenol. 2(1): 120 (1985)
Lachnocladium subcorticale (Schwein.) Burt, Ann. Mo. bot. Gdn 9(1): 66 (1922)
Ramaria chionea (Pers.) Quél., Fl. mycol. France (Paris): 465 (1888)
Ramaria favreae Quél., C. r. Assoc. Franç. Avancem. Sci. 22(2): 489 (1894)
Ramaria krombholzii (Fr.) Bourdot [as 'krombholtzii'], Rev. Sci. Bourb. Centr. Fr. 7: 119-126 (1894)
Ramaria kunzei (Fr.) Quél., Fl. mycol. France (Paris): 464 (1888)
Ramariopsis kunzei var. *deformis* Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 700 (1950)
Ramariopsis kunzei var. *favreae* Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 700 (1950)
Ramariopsis kunzei var. *megaspora* Corner, Proc. Linn. Soc. London 178: 105 (1967)
Ramariopsis kunzei var. *subasperata* Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 700 (1950)
Ramariopsis kunzei var. *sublaevispora* S.S. Rattan & Khurana (as 'sublaevisporum'), Biblthca Mycol. 66: 39 (1978)

FIGURE 76

Basidiomata 40 –60 × 3–4 mm, highly branched, branching irregular, lateral branches dichotomous, narrow, slender, 2 mm wide, apex bifurcate, with distinct stalk, up to 10 mm long, base slightly tomentose, cylindrical, terete in cross section, solid, white, becoming brownish on ageing, context fleshy, fragile, without distinct odour, no positive reaction in $FeCl_3$ and KOH.

Basidiospores 4–5 × 3–4 µm (Q=1–1.1 µm, Q_m=1.14 µm), globose, verrucose, uniguttulate, thin-walled, apiculus up to 0.5 µm, hyaline, inamyloid, cyanophilic in cotton blue. **Basidia** 23–35 × 6–7 µm, clavate, with basal clamp-connection, tetra-sterigmate (up to 5 µm long). **Hymenium** up to 70 µm wide. **Subhymenium** up to 100 µm. **Context** composed of generative hyphae, 3 to 6 µm wide, septate, interwoven, inflated up to 15 µm, thin- walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp connections frequent.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzhi, 24 June 2017, Krishnapriya K., ZGCKP5; 26 June 2018, Krishnapriya K., ZGCKP107; 19 July 2017, Janakikkadu forest, Krishnapriya K., ZGCKP53; Thrissur District, Chimmney, 19 July 2021, Krishnapriya K., ZGCKP208.

Habitat: On soil, in gregarious clusters.

Comments: *R. kunzei* is a species that accommodates a wide range of morphological variations. (Corner 1950, 1970; Furtado *et al*. 2016). *R. bispora*, differs from *R. kunzei* by the bi-sterigmate basidia and the absence of hyphal clamp-connections (Furtado *et al*. 2016). *R. robusta* is a species with white basidiomata differing by its echinulate basidiospores and uninflated hypahe (Matouš *et al*. 2017).

Ramariopsis robusta Matouš & Holec, in Matouš, Holec & Koukol, Czech Mycol. 69(1): 54 (2017)

FIGURE 77

Basidiomata 40–60 × 5–6 µm, branched, polychotomous, irregular, dichotomous towards the apex, broad, apex acute and mostly bifurcate, terete when young, ellipsoid when matures, solid, whitish, with a pale brownish tinge on ageing, brownish on drying, context fleshy, fragile, with a fungoid odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 4–6 × 4–5 µm (Q=1–1.2 µm, Q_m=1.16 µm), subglobose to ellipsoid, aguttulate to uniguttulate, echinulate (up to 1 µm long), thin-walled, hyaline, apiculus prominent (1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–45 × 4–5 µm, clavate to cylindrical, with basal clamp-connection, sterigmata 2 to 4 (up to 7 µm long). **Hymenium** up to 40µm wide. **Subhymenium** up to 20 µm wide. **Context** composed of generative hyphae, 3–8 µm wide, septate, thick-walled (1 µm), hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kozhikode District, Peruvannamuzhi; 24 June 2017, Krishnapriya K., KP14; ZGCKP95; Janaki Forest, 02 October 2019, Krishnapriya K., ZGCKP193.

Habitat: On soil, in gregarious clusters

Comments: The present specimen fits with the description by Matouš *et al*. (2017). The present specimen may be misidentified as *R. kunzei* from the field, but *R. robustus* differs by its echinulate basidiospores and uninflated hyphae (Matouš *et al*. 2017).

Genus *Pterula*

The basidiomata branched, branches filiform, slender, hymenium generally absent towards base. Basidiospores smooth. Cystidia present. Hyphae dimitic, generative hyphae are thin-walled, and with clamp-connections.

Pterula verticillata Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 699 (1950)

FIGURE 78

Basidiomata 60–70 × 4–5 mm, branched, branching verticillate, branches filiform, up to 2 mm wide, apex acute, glabrous, pruinose towards the base, with a distinct stalk, stalk up to 10 mm long, cylindrical, solid, terete in cross section, dull white, stalk brownish, apex darker on drying, context fleshy, without distinct odour, positive reaction in Fe_3Cl and KOH (yellowish).

Basidiospores 6–7 × 4–5 µm (Q=1–1.2 µm, Q_m=1.16 µm), broadly ellipsoid, smooth, aguttulate, thin-walled, apiculus not prominent (0.5 µm), hyaline, inamyloid, cyanophilic in cotton blue. **Basidia** 20–30 × 6–7 µm, clavate to cylindrical, with basal clamp-connection, sterigma 2 to 4 (up to 4 µm long), cyanophilic in cotton blue. **Cystidia** present, 40–50 × 6–7 µm, versiform, thin-walled, hyaline. **Hymenium** up to 120 µm wide. **Subhymenium** up to 60 µm wide. **Context** composed of dimitic hyphae. Generative hyphae 4 to 7 µm wide, septate, agglutinated, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Skeletal hyphae 3 to 5 µm wide, thick-walled (2 µm wide), yellowish. Hyphal clamp-connections present.

Specimen collected: India, Kerala State, Malappuram District, Nilambur Teak Museum, O3 July 2018, Krishnapriya K., ZGCKP138; Kannur District, Aralam, 28 June 2019, Krishnapriya K., ZGCKP167

Habitat: on soil, gregarious, found growing near *Terminalia* sp.

Comments: *P. robusta* Corner resembles the present specimen by its verticillate branching pattern, but differs by its deep brown and robust basidiomata. *P. subulata* differs by its pale yellowish basidiomata and larger basidiospores (8–10 × 5–7 µm).

Genus *Pterulicium*

Basidiomata simple or sparingly branched, decurved, inverted, branches polychotomous to dichotomous. Hymenium waxy, amphigenous. Basidiospores smooth and hyaline. Hyphae dimitic, with skeletal hyphae, and thick-walled generative hyphae, without hyphal clamp-connections, cystidia absent.

Pterulicium secundirameum (Lév.) Leal-Dutra, Dentinger & G.W. Griff., in Leal-Dutra, Griffith, Neves, McLaughlin, McLaughlin, Clasen & Dentinger, IMA Fungus 11(no. 2): 18 (2020)

Basionym:
Clavaria secundiramea Lév. 1844

Synonyms:
Clavaria secundiramea Lév., Annls Sci. Nat., Bot., sér. 3 2: 216 (1844)
Deflexula secundiramea (Lév.) Corner, Beih. Nova Hedwigia 33: 199 (1970)
Pterula palmicola Corner, Ann. Bot., Lond., n.s. 16: 568 (1952)
Pterula secundiramea (Lév.) Speg., Boln Acad. nac. Cienc. Córdoba 11(4): 466 (1889)

FIGURE 79

Basidiomata 10–40 × 2–3 mm, pendent, inverted, fasciculate in cluster, irregular spine-like branching, branches downward pointing, branching mostly bifurcate towards apex, apex acute to pyxidate, cylindrical, terete in cross section, solid, glabrous, slightly pruinose towards the base, cream, pale brownish with ageing, darker at the base, brownish on drying, context fleshy, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiopsores 10–15 × 6–8 µm (Q=1.4–2.4 µm, Q_m=2.5 µm), broadly fusiform, guttulate, smooth, slightly thick-walled (up 0.5 µm wide), hyaline, apiculus prominent ((up to 1 µm long), inamyloid, cyanophilic in cotton blue**. Baisida** 20–25 × 7–8 µm, aguttulate, cylindrical to broadly clavate, with basal clamp-connection, sterigmata 1 to 2 (up to 10 µm long), cyanophilic in cotton blue. **Hymenium** up to 50 µm wide. **Subhymenium** not distinct. **Context** dimitic, skeletal hyphae 2–3 µm wide, generative hyphae septate, 3–4 µm wide, hyaline, thin-walled, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Palakkad District, Mukkali, 04 July 2019, Krishnapriya K., ZGCKP174.

Habitat: On the trunk of *Terminalia* sp. in gregarious clusters.

Comments: The present specimen fits with the species description by Corner (1950). *P. fasciculare* resembles the present specimen, but differs by the simple basidiomata and globose basidiospores in the former (Corner 1950).

Pterulicium subsimplex (Henn.) Leal-Dutra, Dentinger & G.W. Griff., in Leal-Dutra, Griffith, Neves, McLaughlin, McLaughlin, Clasen & Dentinger, IMA Fungus 11(no. 2): 18 (2020)

Basionym:
Pterula nivea Pat. 1902

Synonyms:
Deflexula nivea (Pat.) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 398 (1950)
Deflexula pacifica (Kobayasi) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 399 (1950)
Deflexula subsimplex (Henn.) Corner, Ann. Bot., Lond., n.s. 16: 279 (1952)
Deflexula subsimplex var. multifida Corner, Ann. Bot., Lond., n.s. 16: 282 (1952)
Mucronella pacifica Kobayasi, Bot. Mag., Tokyo 53: 160 (1939)
Pterula nivea Pat., Bull. Soc. mycol. Fr. 18(2): 174 (1902)
Pterula subsimplex Henn., Hedwigia 36(4): 197 (1897)
Pterulicium subsimplex var. multifidum (Corner) Leal-Dutra, Dentinger & G.W. Griff., in Leal-Dutra, Griffith, Neves, McLaughlin, McLaughlin, Clasen & Dentinger, IMA Fungus 11(no. 2): 18 (2020)

FIGURE 80

Basidiomata 10–30 × 1–2, simple, downwards pointing, rarely branched, cylindrical, apex acute, terete in cross section, solid, glabrous, pale ochraceous, becoming brownish on drying, base blackish, context fleshy, without distinct odour, no positive reaction in Fe_3Cl and KOH.

Basidiospores 12–15 × 6–9 µm (Q=1.5–2.5 µm, Q_m=2.7 µm), broadly fusiform, uniguttulate, smooth, slightly thick-walled (up 0.5 µm wide), hyaline, apiculus prominent ((up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 35–50 × 7–9 µm, clavate, without basal clamp connection, tetra-sterigmate (up to 7 µm long). **Hymenium** up to 40 µm wide. **Subhymenium** not distinct. **Context**

dimitic**,** skeletal hyphae 3–5 µm wide, generative hyphae 3–5 µm wide, septate, hyaline, thick-walled (up to 1 µm wide), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections absent.

Specimen examined: India, Kerala State, Kannur District, Aralam, 29 June 2019, Krishnapriya K., ZGCKP166.

Habitat: On decayed wood.

Comments: The present specimen fits with the description by Corner (1970). *P. sprucei* resembles the present specimen by the colour of the basidiomata, but differs by the presence of angular basidiospores (Corner 1970).

Genus *Typhula*

Basidiomata filiform to club-shaped with distinct stipe and head, often arising from the sclerotium, normally white, rarely pink to brownish. Basidiospores smooth. Hyphae monomitic, with or without clamp-connections, inflated, sclerotium small, generally yellow, brown, or black.

Typhula abietina Fuckel) Corner, Monograph of *Clavaria* and allied Genera, (Annals of Botany Memoirs No. 1): 664 (1950)

Basionym:
Pistillaria abietina Fuckel 1871

Synonymy:
Pistillaria abietina Fuckel, Jb. nassau. Ver. Naturk. 25-26: 292 (1871)

FIGURE 81

Basidiomata 10 × 1–5 mm, simple, with distinct stalk and head, stalk up to 3 mm long, 1–2 mm wide, head up to 7 mm long, fertile, solid, glabrous, apex sub-acute, creamy white, with a pale yellowish tinge, becoming brownish on drying, without sclerotium, context fleshy, without distinct odour, no reaction in Fe_3Cl.

Basidiopsores 8–10 × 6–8 µm (Q=1–1.4 µm, Q_m=1.3 µm), subglobose to ovoid, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 30–40 × 5–6 µm, guttulate, cylindrical, with basal clamp-connection, bi-sterigmate (up to 8 µm long). Cystidia absent. **Hymenium** up to 10 µm wide. **Subhymenium** not distinct**. Context** composed of generative hyphae, 5–10 µm wide, septate, inflated up to 20 µm wide, thin-walled, hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Kannur District, Aralam, 08 August 2021, Krishnapriya K., ZGCKP219.

Habitat: On decayed twigs, in gregarious groups.

Comments: The present specimen fits with the description of *T. abietina* by Corner (1950). *T. euphorbiae* resembles the present specimen, but differs by the pubeulous stem and pip-shaped basidiospores in the former (Corner 1950). *T. ovata* differs from the present specimen by the distinct stem with a blackish colour (Corner 1950).

Typhula sclerotioides (Pers.) Fr., Epicr. syst. mycol. (Upsaliae): 585 (1838) [1836-1838]

Basionym:
Phacorhiza sclerotioides Pers. 1822

Synonymy:
Phacorhiza sclerotioides Pers., Mycol. eur. (Erlanga) 1: 11 (1822)

FIGURE 82

Basidiomata 5–10 × 0.2–0.5 mm, simple, head up to 5 mm long, fertile, cylindric, elongate, soild, apex obtuse, translucent white, becoming dull white when mature, stalk up to 5 mm long, distinct, filiform, pubescent, stalk translucent white when young, becoming greyish with maturity, sclerotium blackish, context fleshy, without distinct odour, no reaction in Fe_3Cl.

Basidiospores 4–6 × 4–5 µm (Q=1–1.2 µm, Q_m=1.16 µm), ellipsoid to ovate, uniguttulate, smooth, thin-walled, hyaline, apiculus prominent (up to 1 µm long), inamyloid, cyanophilic in cotton blue. **Basidia** 20–25 × 6–7 µm, guttulate, clavate, with basal clamp-connection, 2 to 4 (up to 7 µm long). **Cystidia** 55–60 × 7 µm, rare, cylindrical to clavate, hyaline, inamyloid. **Hymenium** up to 15 µm. **Subhymneium** not distinct. **Cortex** composed of generative hyphae, 4 to 10 µm wide, septate, inflated up to 12 µm, thin- to slightly thick-walled (0.5 µm), inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present. Hyphae of sclerotium agglutinated, up to 6 µm wide, greyish, clamp-connections absent.

Specimen examined: India, Kerala State, Kannur District, Aralam, 07 August 2018, Krishnapriya K., ZGCKP218.

Habitat: Scattered on decayed leaves.

Comments: Characters of the present specimen fits with the description of the species given by Corner (1950). *T. variabilis* resembles the present specimen macroscopically, but differs by its larger basidiospores (9–16 × 4–6 µm), and by the absence of cystidia. *T. corallina* differes by its forked basidiomata, and bi-sterigmate basidia (Corner 1950).

Genus *Macrotyphula*

Basidiomata simple, linear, narrowly filiform, without sclerotia. Basidiospores smooth, hyaline. Cystidia present. Hyphae monomitic, inflated, with or without clamp-connections.

Macrotyphula phacorrhiza (Reichard) Olariaga, Huhtinen, Læssøe, J.H. Petersen & K. Hansen, Stud. Mycol. 96: 175 (2020)

Basionym:
Clavaria phacorrhiza Reichard [as 'phacorihiza'] 1780

Synonyms:
Clavaria juncea var. phacorrhiza (Reichard) Gillot & Lucand, Bull. soc. Hist. nat. Autun 4: 441,*(1891)*
Clavaria phacorrhiza Reichard [as 'phacorihiza'], Schr. naturf. Fr. Berlin 1: 315 (1780)

Clavaria phacorrhiza var. epiphylla Alb. & Schwein., Consp. fung. (Leipzig): 293 (1805)
Sclerotium complanatum Tode, Fung. mecklenb. sel. (Lüneburg) 1: 5 (1790)
Sclerotium scutellatum Alb. & Schwein., Consp. fung. (Leipzig): 74 (1805)
Typhula complanata (Tode) de Bary, Vergl. Morph. Biol. Pilze (Leipzig): 44 (1884)
*Typhula phacorrhiza (*Reichard) Fr., Observ. mycol. (Havniae) 2: 298 (1818)
Typhula phacorrhiza var. complanata (Tode) Sacc., Syll. fung. (Abellini) 8: 744 (1889)
Typhula phacorrhiza var. heterogenea Berthier, Monographie des Typhula, Pistillaria et des genres voisins: 197 (1976)

FIGURE 83

Basidiomata 20–60 × 1–4 mm, simple, unbranched, filiform to cylindrical, narrower towards the base, glabrous, apex acute, solid, terete in cross section, creamy white, becoming brownish on drying, darker towards the apex on ageing, blackish towards the base, context fleshy, without distinct odour, no reaction in Fe_3Cl and KOH.

Basidia 20–30 × 6–6 µm, clavate, without basal clamp-connection, 2 to 4 (up to 12 µm long). **Cystidia** 40–60 × 6–8 µm, cylindrical, narrowly lageniform, inamyloid, hyaline. **Hymenium** up to 50 µm. **Subhymneium** not distinct. **Cortex** composed of generative hyphae, 4 to 10 µm wide, septate, inflated up to 15 µm wide, thick-walled (0.1 µm), hyaline, inamyloid, cyanophilic in cotton blue. Hyphal clamp-connections present.

Specimen examined: India, Kerala State, Palakkad District, Parambikulam, 05 June 2022, Krishnapriya K., ZGCKP246.

Habitat: Scattered, on decaying leaves.

Comments: The present specimen fits with description of *T. phacorrhiza* by Corner (1950). Olariaga *et al.* (2020), based on the phylogenetic studies, placed *T. phacorrhiza* in the genus *Macrotyphula. T. incarnata* is a related species, which differes from the present specimen in its branched, pink basidiomata (per description of Corner 1950).

PURE CULTURE ESTABLISHMENT

Pure cultures of 15 clavarioid species were isolated during the study. Of these, 4 species belonged to the genus *Ramaria*, 3 species belonged to the genus *Clavaria*, 2 to the genus *Clavulinopsis*, 3 to the genus *Tremellodendropsis*, 2 species to the genus *Lachnocladium* and 1 to the genus *Phaeoclavulina* (Table 9).

TABLE 9: List of species having pure cultures generated in the study

Sl. No.	Species	Culture isolate number
1	*Ramaria subaurantiaca*	ZGCKPCUL231
2	*R. gracilis*	ZGCKPCUL162
3	*R. grandis*	ZGCKPCUL249
4	*R. stricta*	ZGCKPCUL170
5	*Phaeoclavulina cokeri*	ZGCKPCUL235
6	*Clavaria fumosa*	ZGCKPCUL175
7	*C. fragilis*	ZGCKPCUL172
8	*C. gibbsiae*	ZGCKPCUL233
9	*Clavulinopsis aurantiocinnabaria*	ZGCKPCUL128
10	*C. appalachiensis*	ZGCKPCUL92
11	*Tremellodendropsis tuberosa*	ZGCKPCUL202
12	*T. flagelliformis*	ZGCKPCUL215
13	*T. pusio*	ZGCKPCUL65
14	*Lachnocladium fulvum*	ZGCKPCUL206
15	*L. flavidum*	ZGCKPCUL207

MOLECULAR CHARACTERIZATION

The present study generated 21 DNA sequences representing 17 species of clavarioid fungi from Kerala. This includes 18 ITS sequences, two LSU sequences and one RPB2 sequence (Table 10).

TABLE 10: List of taxa, voucher numbers and the GenBank accession numbers of sequences (ITS, LSU and RPB2) generated during the present study.

Sl No.	*Taxa*	Voucher No.	ITS	LSU	RPB2
1	*Clavaria cystidiata*	ZGCKP59	MK751792	-	-
2	*Clavaria viriditincta*	ZGCKP247	OP895708	0P627565	-
3	*Clavulina ornatipes*	ZGCKP63	OP627561	-	OP627559
4	*Gomphus zamorinorum*	ZGCKP203A	ON732852	-	-
5	*Gomphus zamorinorum*	ZGCKP203B	ON732853	-	-
6	*Lachnocladium flavidum*	ZGCKP186	OP627560	-	-
	Ramariopsis subtilis	ZGCKP136	OQ030272	-	-
7	*Ramaria subaurantiaca*	ZGCKP231	OP627564	-	-
	Trechispora angulispora	ZGCKP255	OP627566	OP614946	-
8	*Trechispora cystidiata*	ZGCKP152	OP627562	-	-
9	*Trechispora cystidiata*	ZGCKP212	OP627563	-	-
10	*Trchispora echinosporus*	ZGCKP237	OP881892	-	-
11	*Trechispora dealbata*	ZGCKP130	OP948880	-	
12	*Trechispora dealbata*	ZGCKP135	OP901214	-	
13	*Trechispora havencampii*	ZGCKP85	OP881891		
14	*Trechispora havencampii*	ZGCKP160	OP948881		
15	*Trechispora robusta*	ZGCKP131	OP881894		
16	*Trechispora foetida*	ZGCKP154	OP881893		

5. DISCUSSION

Basidiomata of clavarioid fungi were collected from various localities of Kerala State during a period of five years (September 2017-September 2022), and systematic studies were carried out. Seventy-seven species, belonging to 15 genera and six orders (Tremellodendropsidales, Russulales, Gomphales, Trechisporales, Cantharellales, Agaricales) were documented.

Following are the clavarioid taxa documented during the study:

Order Agaricales

Family Clavariaceae

1 *Clavaria citriceps*
2 *C. cystidiata*
3 *C. echinonivosa*
4 *C. fragilis*
5 *C. fumosa*
6 *C. gibbsiae*
7 *C. greletii*
8 *C. luteostirpata*
9 *C. macounii*
10 *C. rosea*
11 *C. sinensis*
12 *C. vermicularis*
13 *C. viriditincta*
14 *C. xylarioides*
15 *C. zollingeri*
16 *Clavulinopsis amoena*
17 *C. appalachiensis*
18 *C. archeri*
19 *C. arnicola*
20 *C. aurantiocinnabarina*
21 *C. brevipes*

22 *C. corneculata*
23 *C. fusiformis*
24 *C. helvola*
25 *C. ochracea*
26 *C. rufipes*
27 *C. semivestia*
28 *C. spathuliformis*
29 *C. spiralis*
30 *C. subartica*
31 *C. sulcata*
32 *C. umbrenella*
33 *Ramariopsis clavuligera*
34 *R. kunzei*
35 *R. ramarioides*
36 *R. robusta*
37 *R. subtilis*
38 *R. tenuiramosa*

Family Pterulaceae

39 *Pterulicium secundirameum*
40 *P. subsimplex*
41 *Pterula verticillata*

Family Typhulaceae

42 *Macrotyphula phaccorhiza*
43 *Typhula abietina*
44 *T. sclerotioides*

Order Cantharellales

Family Aphelariaceae

45 *Aphelaria dendroides*

Family Hydnaceae

46 *Clavulina cinerea*
47 *C. cristata*
48 *C. floridana*
49 *C. humilis*
50 *C. livida*
51 *C. ornatipes*

52 *C. rugosa*

Order Gomphales

Family Gomphaceae

53 *Gomphus zamorinorum*

54 *Phaeoclavulina cokeri*

55 *P. cyanocephala*

56 *Ramaria divaricata*

57 *R. fragillima*

58 *R. gelatinosa*

59 *R. gracilis*

60 *R. grandis*

61 *R. pusilla*

62 *R. stricta*

63 *R. subaurantiaca*

64 *R. subsigmoidea*

65 *R. suecica*

Order Russulales

Family Peniophoraceae

66 *Lachnocladium flavidum*

67 *L. fulvum*

Order Trechisporales

Family Hydnodontaceae

68 *Trechispora angulispora*

69 *T. dealbata*

70 *T. echinosporus*

71 *T. foetida*

72 *T. robusta*

73 *T. cystidiata*

74 *T. havencampii*

Order Tremellodendropsidales

Family Tremellodendropsidaceae

75 *Tremellodendropsis flagelliformis*

76 *T. pusio*

77 *T. tuberosa*

The highest number of clavarioid taxa documented during the study belonged to the order Agaricales. Among these, the family Clavariaceae is represented by the highest number of species (38 species); *Clavulinopsis* (17 species), *Clavaria* (15 spp.), *Ramariopsis* (6 spp.), followed by *Macrotyphula* (1 sp.), *Pterulicium* (2 spp.), *Pterula* (1 sp.) and *Typhula* (2 spp.). In the order Gomphales, the genus *Ramaria* represents the highest number of species (10 spp.). The genus *Clavulina* has the highest number of species (7 spp.) in the order Cantharellales, followed by *Aphelaria* (1 sp.). The orders Tremellodendropsidales, Russulales, and Trechisporales are represented by a single family each. Three species in Tremellodendropsidaceae (Tremellodendropsidales), two species in Pheniophoraceae (Russulales) and seven species in Hydnodontaceae (Trechisporales) have been documented.

Four species new to science have been discovered and are described based on morphological and molecular data. *Clavaria cystidiata* Krishnapriya & T. K. A. Kumar, *Clavaria viriditincta sp. nov.* Krishnapriya & T. K. A. Kumar, *Gomphus zamorinorum sp.nov.* Krishnapriya & T. K. A. Kumar, and *Trechispora cystidiata sp. nov*. Krishnapriya & T. K. A. Kumar are the new species. A new taxonomic combination, *Trechispora anguslispora* ((Berkeley) Corner) Krishnapriya & T. K. A. Kumar is proposed during the study. A *nomen novum*, *Trechispora corneri* ((Berk. & Broome) Corner) Krishnapriya & T. K. A. Kumar is recommended during the present study.

The following 22 taxa are new records to Asia:

Clavaria citriceps, Clavaria echinonivosa, Clavaria greletii, Clavaria macounii, Clavulinopsis archeri, Clavulinopsis ochracea, Clavulinopsis rufipes, Clavulinopsis spathuliformis, Clavulinopsis subartica, Clavulina floridana, Clavulina humilis, Pterulicium secundirameum, Ramariopsis ramarioides, Ramariopsis robusta, Ramaria divaricata, Ramaria gelatinosa, Ramaria subsigmoidea, Trechispora dealbata, Trechispora foetida, Trechispora robusta, Trechispora havencampii, and *Typhula Abietina.*

Following 43 taxa are new records to India:

Aphelaria dendroides, Clavaria citriceps, Clavaria echinonivosa, Clavaria gibbsiae, Clavaria greletii, Clavaria luteostirpata, Clavaria macounii, Clavaria rosea, Clavaria sinensis, Clavaria xylarioides, Clavulinopsis appalachiensis, Clavulinopsis archeri, Clavulinopsis arnicola, Clavulinopsis brevipes, Clavulinopsis ochracea, Clavulinopsis rufipes, Clavulinopsis spathuliformis, Clavulinopsis spiralis, Clavulinopsis subartica, Clavulinopsis umbrenella, Clavulina floridana, Clavulina humilis, Clavulina livida, Lachnocladium flavidum, Lachnocladium fulvum, Phaeoclavulina cokeri, Pterulicium secundirameum, Pterulicium subsimplex, Ramaria divaricata, Ramaria fragillima, Ramaria gelatinosa, Ramaria grandis, Ramaria subsigmoidea, Ramariopsis ramarioides, Ramariopsis robusta, Ramariopsis tenuiramosa, Trechispora dealbata, Trechispora corneri, Trechispora foetida, Trechispora robusta, Trechispora havencampii, Tremellodendropsis flagelliformis, and *Typhula abietina.*

Following 64 taxa are new records to Kerala:

Aphelaria dendroides, Clavaria citriceps, Clavaria echinonivosa, Clavaria fragilis, Clavaria fumosa, Clavaria gibbsiae, Clavaria greletii, Clavaria luteostirpata, Clavaria macounii, Clavaria rosea, Clavaria sinensis, Clavaria vermicularis, Clavaria xylarioides, Clavulinopsis amoena, Clavulinopsis appalachiensis, Clavulinopsis archeri, Clavulinopsis arnicola, Clavulinopsis brevipes, Clavulinopsis helvola, Clavulinopsis ochracea, Clavulinopsis rufipes, Clavulinopsis semivestia, Clavulinopsis spathuliformis, Clavulinopsis spiralis, Clavulinopsis subartica, Clavulinopsis sulcata, Clavulinopsis umbrenella, Clavulina cinerea, Clavulina floridana, Clavulina humilis, Clavulina livida, Clavulina ornatipes, Lachnocladium flavidum, Lachnocladium fulvum, Macrotyphula phaccorhiza, Phaeoclavulina cyanocephala, Pterulicium secundirameum, Pterulicium subsimplex, Pterula verticillata, Ramaria divaricata, Ramaria fragillima, Ramaria gelatinosa, Ramaria grandis, Ramaria pusilla, Ramaria stricta, Ramaria subaurantiaca, Ramaria subsigmoidea, Ramaria suecica, Ramariopsis clavuligera, Ramariopsis ramarioides, Ramariopsis robusta, Ramariopsis subtilis, Ramariopsis tenuiramosa, Scytinopogon angulisporus, Trechispora dealbata, Trechispora corneri, Trechispora foetida,

Trechispora robusta, Trechispora havencampii, Tremellodendropsis flagelliformis, Tremellodendropsis pusio, Tremellodendropsis tuberosa, Typhula abietina, and *Typhula sclerotioides.*

Most of the clavarioid fungi collected and studied were obtained from soil. A few collections were saprobic, living on decayed wood and leaves (*Macrotyphula phaccorhiza, Ramaria gelatinosa, R. stricta, R. gracilis, R. suecica, Pterulicium subsimplex, Typhula abietina*, and *T. sclerotioides),* while some were collected from the living trunk of *Terminalia* species and *Cullenia* species (*Lachnocladium flavidum* on *Terminalia paniculata*, *L. fulvum* on *cullenia* species, *Pterulicium secundirameum* and *Pterula verticillata* on *Terminalia* species). Among the visited collection localities, Thusharagiri forest, and Peruvannamuzhy forest of Kozhikode district, Aralam of Kannur district were found to be rich in species diversity of clavarioid fungi during the south west and north east monsoon seasons.

This study is a major comprehensive work from India on clavarioid fungi, after Thind (1961), and the first comprehensive work from South India. Mohanan (2011) had previously recorded a total of 19 clavarioid taxa from the state. Out of these, eight taxa (*C. laeticolor, C. luteoalba, Ramariopsis pulchella, Ramaria apiculata, R. eumorpha, R. flava, R. pallida,* and *R. versatilis*) were not recollected during this study.

Pure culture establishment

Despite the benefits fungi provide, conservation of this group is important. Global efforts for conservation of fungi are less when compared with other groups of organisms. During this study diversity habitats of clavarioid fungi could be identified as areas of critical importance and requiring urgent habitat protection. As part of the efforts to conserve the clavarioid fungi of Kerala, attempts were made to isolate pure cultures from collected specimens. 15 species were isolated from fresh basidiomata (Table 9). Live cultures are maintained in low temperature storage (4^{o}C) in refrigerator, in the Mycology laboratory of the Zamorin's Guruvayurappan College. Revival of these cultures maintained *in vitro* can help in bringing back the cultures for multiplication and future studies.

Molecular phylogeny

The present study generated 21 DNA sequences (Table 10) representing 17 species from Kerala. This forms the first molecular characterization of many species for which GenBank sequences are unavailable. These newly generated sequences were useful in molecular identification and phylogenetic reconstruction. The molecular study combined with morphological data also helped resolve some of the taxonomic uncertainities that existed in certain groups of clavarioid fungi.

Phylogeny of the order Trechisporales

Seven *Trechispora* species were collected from Kerala during the study. They are *T. angulisporus, T. cystidiata* sp nov., *T. dealbata, T. corneri, T. foetida, T. havencampii,* and *T. robusta*. Until now, there are no other reports of this genus from Kerala state, and from India only one species (*S. angulisporus*) was reported (De 1991; Banerjee 1947). Morphology based species level identification of *Trechispora* is difficult due to the lack of comparable taxonomic characters. Hence, the identitiy of the Kerala collections were confirmed by generating DNA sequences from all the collections (Table 8) and thereby constructing a phylogenetic tree (Fig. 28).

Previous phylogenetic studies by Chikowski *et al.* (2020), Meiras-Ottoni *et al.* (2021), and Liu *et al.* (2022) confirmed the synonymization of *Sytinopogon* in *Trechispora*. But many taxa in *Scytinopogon* were retained in that genus by the lack of molecular data. Our tree confirmed the tree topology of the earlier phylogenetic studies in Trechisporales, with good bootstrap values for all clades. The tree confirmed the placement of this species in clavarioid clade (clade that had clavarioid taxa) that included *T. havencampii, T. termitophila, T. robusta*, and *Scytinopogon* sp. However, this monophyletic clade obtained a low support value (<50%). *T. cystidiata sp. nov*. is also a clavarioid taxa setteled with the clavarioid clade. *S. cryptomeroides*, *S. schinosporus* and *S. parvus* are the clavarioid taxa, which are not formally transferred to *Trechispora*. Out of this, *S. cryptomeroides* and *S. schinosporus* still lack molecular sequences. Our study generated sequence for *S. echinosporus* and was included in the molecular phylogenetic analysis. In that, *S. echinosporus* settled with the clavarioid *trechispora* clade, that support the formal transfer of that species to

Trechispora. However, a species with that specific epithet (*echinospora*) already exists in the genus *Trechispora* (a resupinate species, *T. echinospora*, described earlier (Phookamsak 2019). Hence, in order to avoid the duplication of the species name during new combination, a *nomen novum* has to be proposed. We propose the *nomen novum* as *T. corneri* in the study.

Our phylogenetic study included all the collected *Trechispora* species from Kerala, and the newly generated DNA sequences for all the collections were included in the phylogenetic analysis. Phylogenetic identification confirmed with morphology-based identification. None of the molecular phylogenetic study so far conducted included *S. angulisporus*. The taxon is considered under both *Scytinopogon* and *Clavulina* (according to *Index fungorum*, accessed on 01 January 2023). The morphology of the species is more related to *Trechispora* by its verrucose, angularly ellipsoid basidiospores, and small, broadly clavate, tetra-sterigmate basidia. Where as, *Clavulina* is characterized by smooth, subglobose to globose basidiospores and cylindrical, bi-sterigmate basidia. Our study included the molecular sequence of *S. angulisporus* and compared it molecularly with the *Trechispora* and *Clavulina* group. Interestingly, the species from Kerala settled with the monophyletic clade containing clavarioid *Trechispora* species. Sequences of two unidentified *Scytinopogon* species also settled along with the Kerala collection. Based on our phylogenetic analysis, we confirmed the placement of this species as belong to *Trechispora* rather than in *Clavulina*. *S. angulisporus* has not been formally transferred to *Trechispora* yet. Hence a new combination for the species is hereby proposed as *T. angulispora*.

It was reported that many clavarioid basidiomata in *Trechispora* are white (Furtado *et al.* 2021). Here three species were reported as so. They are *T. dealbata*, *T. robusta* and *T. angulispora*. Newly generated sequence of *T. dealbata* is nested with *T. dealbata* species from Brazil in a well-supported clade with 100% BS. *T. robusta* also forms a well-supported sister clade to *T. robusta* species from Brazil. Pigmented species of *Trechispora* collected during this study are *T. foetida*, *T. corneri, T. havencampii,* and the novel species *T. cystidiata.* All the above species appeared as a strongly supported clade within the order Trechisporales (Fig. 28).

6. SUMMARY

Clavarioid fungi are a polyphyletic group of basidiomycotan fungi belonging to different orders of the class Agaricomycetes, often studied as a group because of the peculiar similiarity of basidiomata. Basidiomata in this group are club to coral shaped. Most are saprobes, and few forms symbiotic, and rarely pathogenic associations. They grow both in temperate and tropical climates and are well documented around the world. A monographic account of clavarioid fungi from the northern parts of India exist. However, fungi with clavaraioid basidiomata have not been adequately documented from South India. Hence, a study was conducted to document the diversity of this fungi from Kerala. Both morphological and molecular taxonomic methods were employed during this study, which was conducted during 2017-2022. During the study, 77 taxa belonging to 15 genera and six orders (Tremellodendropsidales, Russulales, Gomphales, Trechisporales, Cantharellales, Agaricales) were documented. Four taxa new to science were discovered, one *nomen novum*. and one new combination were formally proposed. Out of the total taxa documented, 22 were new continental reports, 43 were new records to India, and 64 species are new records to Kerala. From the Kerala collections, pure cultures of 15 species were isolated. The study constitutes the first monographic attempt on tropical clavarioids incorporating morphological and molecular identification. The live cultures are maintained in the Fungal Diversity lab of the Zamorin's Guruvayurappan College as part of conservation effort. 21 DNA sequences were newly generated. Molecular data was coupled with morphological characters wherever possible, and molecular phylogenetic analyses aided accurate identification of enigmatic species. A molecular phylogenetic study including all species of Trechisporales with molecular sequences was conducted and phylogenetic trees were generated and interpreted. The present taxonomic account of the clavarioid fungi of Kerala forms the first largest comprehensive study of the group from India after 60 years, and the first from South India. Several tropical species that have never been collected after their original descriptions have been recollected, many were molecularly characterized, and their DNA sequences were deposited in public reprositories. This is the first monographic treatment of clavarioid fungi from Kerala. The study adds to the knowledge of tropical clavarioids.

7. RECOMMENDATIONS

Clavarioid fungi are a least explored group of fungi from Kerala State. The present study indicates the diversity richness of this group in the state. The documentation of clavarioid fungi during this study was based on collection of basidiomata from different regions of Kerala. As all clavarioid species need not fruit regularly throughout the seasons at fixed habitats, many species may have evaded collection, and some may have been overlooked during the five-year study period. Hence, there may be more species of clavarioid fungi remaining to be characterized and discovered. Destruction of natural habitats adversely affect the survival of this ecologically sensitive group. Hence, strategies should be devised and employed for long term *in vitro* and *in vivo* conservation. Special efforts and studies on developing and standardizing protocols for conservation are essential.

Besides having major ecological roles, clavarioid fungi are important economically, especially in medicine and agriculture. The species have therapeutic and nutritional importance as evidenced by the numerous published scientific reports. Many species are edibile, and are rich sources of bioactive secondary metabolites such as quercetin, chrysin, pinocembrin, protocatechuic, vanillic acids, gallic acid, p-hydroxybenzoic acid, p-coumaric acid, caffeic acid, cinnamic acid, β-carotene, lycopene, ascorbic acids, anthocyanidins, and tocopherol. Clavarioid fungi are good sources of neutraceutical compounds, antioxidents, antibacterials, and produce chemicals that are anticancerous, anti-fungal, anti-proliferative, immunostimulatory and anti-inflammatory. Several enzymes, such as lignocellulolytic enzymes are also produced by this group. A wide screening of these fungi should be carried out to isolate, identify, and utililize the various bio-active compounds. Studies that can generate high quality genome sequences from these fungi can help reveal the genes and the unique secondary metabolic pathways involved in the production of compounds that have biological and applied roles. Studies devoted to whole genome analyses, phytochemical screening and bioprospecting of clavarioid fungi can be recommended as having scope for extended future studies.

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