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Advances in the Taxonomy of Conidial Fungi

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Introduction

Nearly forty years ago, an interesting hypocrealean ascomycete fungus was collected on dead twigs of *Macaranga Indica* Wight (Family: Euphorbiaceae), in the foothills Western Ghats, Karnataka State, India and single ascospores of the fungus in agar culture produced a synnematous, phialidic, conidial, hyphomycete (imperfect) state which was described as *Putagrivam sundaram* Subram. & Bhat (Subramanian and Bhat (1978). This microscopic conidial fungus was considered attractive because it had long synnemata with symmetrically flaring tip, monophialidic conidiogenous cells with distinct, apical, cup-shaped collarette, and fusiform, septate, hyaline conidia with papillate base and acute apex. The fungus was truly charming when looked under a microscope (Fig. 1). A few months later, Subramanian and Bhat (1978a) described the ascomycete (perfect) state, with golden yellow coloured, solitary or grouped perithecia, cylindric-clavate, unitunicate asci and 1-septate, reniform, big, hyaline, ascospores, as *Peethambara sundara* Subram. & Bhat (Fig. 2a, 2b). In subsequent collecting trips to the same locality, the authors encountered the fungus but never both states together. The ascomycete state was parked in the family Nectriaceae of the order Hypocreales *sensu lato* in the Kingdom Fungi. Though aware of physical connectivity between *Peethambara sundara* (perfect state) and *Putagrivam sundaram* (imperfect state), at least in culture and that these two fungi are truly a single entity, the authors opted to maintain two biological names to the same fungus-complex, at that point of time. Why....?

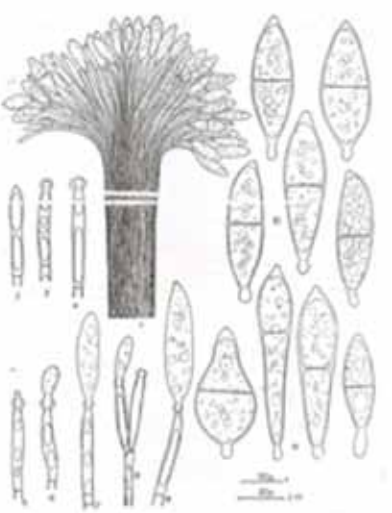

Fig. 1. *Putagraivam sundaram* (Extracted from Subramanian & Bhat, 1978).

Taxonomy of fungi

The christening (= naming) and systematic grouping (= classification) of fungi, similar to plants, are governed by the International Code of Nomenclature for Algae, Fungi and Plants or ICN (formerly, International Code of Botanical Nomenclature or ICBN). This Code, first promulgated in 1857, has been periodically reviewed and upgraded by the International Association for Plant Taxonomy (IAPT) at the International Botanical Congress (IBC) held once in five years. The Code-renewal-practice is a continued process and the latest meet of IBC was held in Melbourne in June 2011 (McNeill *et al*., 2012). Similar to plants, fungi are organisms with enormous diversity and plurality and, therefore, the nomenclature and classification of fungi have been a challenging exercise since the time of their recognition (Kirk *et al*., 2008).

Diversity in Fungi

Fungi are eukaryotic, achlorophyllous and unicellular or filamentous microorganisms. Being non-photosynthetic, they subsist on pre-formed organic matter of plant and animal origin, as saprophytes, parasites or mutualists. They secrete a variety of enzymes and are able to degrade organic material of

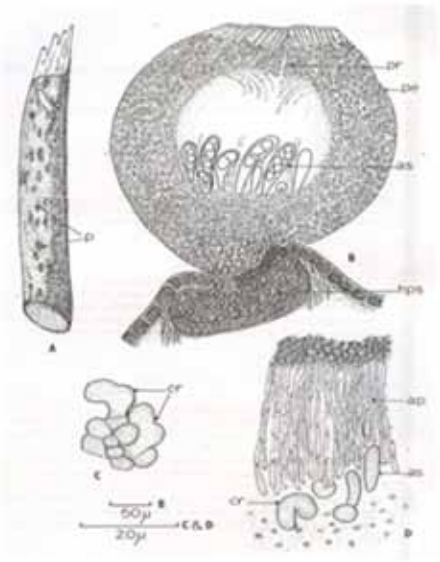

Fig. 2a. *Peethambara sundara* (Extracted from Subramanian and Bhat, 1978a).

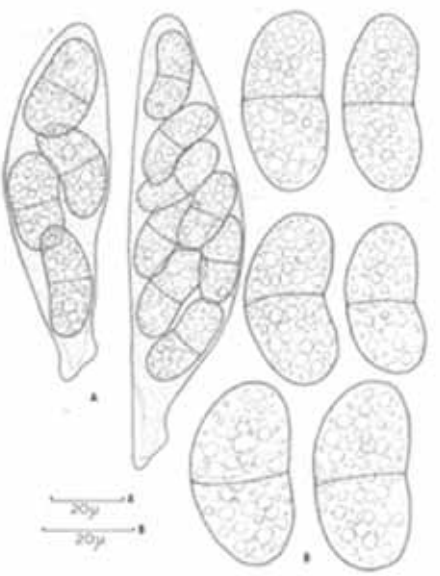

Fig. 2b. *Peethambara sundara* (Extracted from Subramanian and Bhat, 1978a).

any kind on earth. Fungi live in a wide variety of environments, from arctic to tropics; from sea to inland mountains; from deep sea to high aerials (Bhat, 2010). All these adjustments in fungi led to their vast diversity in shape, form and function. In number, fungi are second to insects in the living world. The fungi reproduce by both asexual and sexual methods. The asexual mode of fungal reproduction is said to be quite simple wherein the nucleus divides mitotically and the corresponding vegetative hyphal cell pinches of into tiny propagules called conidia. In the sexual reproductive process, nuclei of opposite mating types fuse to form a diploid, in designated reproductive cells, which undergoes meiosis and results with sexual spores. In higher taxa level, the fungi are grouped based on the kind of sexual spores that they produce, namely, ascospores in Ascomycota and basidiospores in Basidiomycota. The asexual mode of fungal life cycle is known as anamorph and the sexual phase teleomorph. A fungus in its full form, with both sexual and asexual stages, is known as a holomorph (Bhat, 2010).

In most ascomycetous and some basidiomycetous fungi, the sexual and asexual phases are encountered in different periods of time and often in distant places. The two phases of fungi often exhibit contrasting morphology and, even an experienced mycologist recognizes the different states of the same fungus as two different fungi. *Peethambara sundara* and *Putagraivam sundaram* complex is one such example (Subramanian and Bhat, 1978, 1978a). This is a case of plurality or pleomorphism in fungi where the same fungus appears in different forms.

Why names, after all?

A large number of fungi are so far known only by their asexual states which we call as conidial fungi or anamorphic fungi. The sexual states in numerous of these have so far been not seen in nature or in culture and there is no easy way to know of their existence either. Therefore, earlier mycologists who encountered only these conidial fungal forms established a new phylum-level taxon in the Kingdom Fungi called Fungi Imperfecti or Deuteromycotina to accommodate them (Ainsworth and Bisby, 1971). Though artificial, this arrangement became handy and useful to all those working on fungi, be it a fungal systematist, plant pathologist, geneticist, biochemist or drug-discoverer. Such naming arrangement was easily accepted because the conidial fungi or fungi imperfecti are important to human society in many ways. The fungi causing destructive diseases on crop plants, ornamentals and wild trees and pet animals and humans and those producing invaluable life-saving drugs, are all in their asexual states. Most of the foliar pathogens in agricultural crops are conidial fungi; almost all antibiotics and immuno-suppressant drug producing forms are fungal anamorphs; nearly two third of industrially useful

enzymes are derived from asexually reproducing fungi. In Deuteromycotina, the fungi are known only in the asexual mode of reproduction. In the last century, thousands of such conidial fungi were discovered and named (Bhat, 2010). Even within this taxonomic system, many described fungi were known to exhibit more than one morphological form, a filamentous and a yeast form. There was provision to accommodate such pleomorphic fungi with different names. Once identified, people did not bother to look further at their sexual state or holomorphs (Kirk *et al*., 2001). This was also the reason why the two forms of the same fungus introduced in the beginning of this paper had different names, at that point of time.

Advances in fungal taxonomy and nomenclature

All along in the history of taxonomy, assigning correct names and classifying the fungi in a natural system has been a daunting task, especially to those with more than one form. The ICBN provided room in the Vienna Code in the form of Article 49 which had provisions to name pleomorphic fungi based on any form, not necessarily the sexual state. According to Article 59 of the ICBN, introduced at a later stage, names based on teleomorphs were considered legitimate. This implied that names of fungi based only on anamorphs (asexual states) remained as form names. This unfortunately also led to a confused situation in conidial fungi, i.e. the pleomorphic fungi with more than one name, one legitimate name and another form name. The IBC Melbourne Code 2011 took note of these confusions and serious efforts are now underway to address and remedy the taxonomy and nomenclature status of conidial fungi (Mc Neill *et al*., 2012).

Last twenty five years saw tremendous advancement in our understanding of fungi, especially with the advent of PCR techniques, multigene molecular sequence analyses of rDNA and use of computer-based statistical tools. These provided support to prove that different states of a single fungus (anamorph + teleomorph), at molecular level, are genetically identical and connectable (holomorph). This understanding led to needful and pragmatic amendments in Article 59 at the Melbourne IBC (Mc Neill *et al*., 2012).

Melbourne IBC and the future

There is a phenomenal increase in the number of publications on taxonomy and phylogeny of new fungi, in the recent times, all with abundant molecular sequence data. This underlies the fact that there is a growing realization that morphological details alone will not be sufficient to describe the conidial fungi. The IBC 2011, held in Melbourne, Australia discussed this issue in detail. It was stressed in the Melbourne Congress that not only we need to provide molecular sequence data of highly conserved genes but also deposit details of the fungi in

designated international repositories. Another constructive advancement in the taxonomy of fungi has been the declaration by the International Mycological Association (IMA) that in future one fungus will have only one name, also called as Amsterdam Declaration 2011. This declaration, One Fungus = One Name, adopted and endorsed by the International Botanical Congress held in Melbourne in June 2011, is detailed out in the Melbourne Code of ICN (Mc Niell *et al*., 2012). In this new system, the name of a fungus typified either by its anamorph or teleomorph is considered acceptable. According to the Melbourne Code, effective from 1st January 2013, a name, be given to the asexual (anamorph) or sexual (teleomorph) phase, becomes legitimate when proved as part of the same holomorph. It is hoped that this system will ensure each fungus with only one name, in the future.

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