Inventorying microbial diversity: new challenges for India

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Microbes, which include algae (especially blue-green algae), protozoa, fungi and bacteria (Eubacteria and Archaea) are essential components of the ecosystem. They play a key role in maintaining the Earth's ecosystem. Fungi, an 'appendage of botany' now have its own status of kingdom. Recent studies have revealed two more kingdoms – Chromista and Protozoa as segregate members[1,2], which have been extensively studied by mycologists and zoologists.

Since the Rio-92 conference[3], inventorying fungal biodiversity (fungi *s. l.*) is on the agenda of most governments. These are important bioresources which should be conserved and exploited for beneficial use. They are well known for their use in agriculture, industry, human health and environment. Earlier record of Indian fungi, *Sensu lato* recognized as the 'fungi of India'[4,5] or as regional lists, includes genera, species, habitat, location and reference. Except for *Fungi of India* by E. J. Butler and G. R. Bisby, revised by R. S. Vasudeva and published as the second edition in 1960 by ICAR with few major synonyms and taxonomic status (given as comments), none of the others contained this information. Only names published in the literature were compiled without their authenticity or with current nomenclatural status. Another compilation Plant Diseases of India[6] contained information on bacteria and viruses (not included as microbes) associated with plant diseases. This information is 25 years old. Moreover, the compilation lacks much information when compared to parallel work that appeared in the United States[7].

According to various biodiversity assessments, the number of fungi in India[8] is *c.* 27,000 which is less compared to the total number of known fungi. Earlier, species of fungi were erected by plant pathologist on the basis of host specificity or differences in their morphology, whereas species are now recognized based on molecular studies, ultra-structural morphological or anatomical features observed by SEM/TEM and other parameters like biochemical variability. The change in generic concepts using various molecular methods for genus delimitation changed the status of several genera in almost all groups, including anamorphic fungi[2,9].

Generic and species synonym may reduce the number of fungi drastically, which are indexed in lists and other compilations. The number of fungi in India is too low than the number of plant species known. In India, out of 15,500 species of flowering plants 5700 are endemic. According to Hawksworth's[10,11] conservative estimates (of 1 : 6) for the plant–fungi ratio on the basis of data from a temperate country (Britain, the most thoroughly studied land area for fungi), the number of fungi should be 93,000, excluding those on insects, animals, fungicolous and lichens. As evidenced from common cultivated plant species like banana, sugar cane, wheat, maize and Australian tree *Eucalyptus*, the number of fungi associated with plant species in the tropics is considerably high. Currently, some genera like *Aspergillus*, *Penicillium*, *Fusarium* and *Colletotrichum* are drastically revised, while species in the genera like *Cercospora*, *Phoma*, *Phyllosticta* and *Phomopsis*, and many host-based species have no nomenclatural status. Names of these lists should be thoroughly checked for their present nomenclatural status, with the help of recent monographs and the current literature and updated accordingly to know the correct number of fungi.

There are untouched collections of herbaria that have been deserted due to paucity of specialists, taxonomists and with the denial of international collaboration in the form of Biodiversity Acts 2002, 2004. There is no herbarium index for the country and the collections in their possession. Similarly, there is no directory of taxonomists, scientists or specialists who can be contacted for species identification, thus resulting in an unindexed bioresource.

The culture collections meant for *ex situ* conservation in the living state are in poor condition. Presently, there are 14 culture collections in India with only 10,000 fungal cultures in our repository[12]. There are only one or two taxonomists, that too mostly microbiologists, biochemists and molecular taxonomists. So far, none of the culture collection centres has published any monograph similar to their counterparts, viz. CBS (The Netherlands) or CABI (UK). Monographs from private herbaria or culture collections have been published recently[13–15].

There should be regular inflow of cultures into these centres from various geographic locations rich in biodiversity through systematic mapping. After 20 years of Rio 92, there is no systematic mapping of microbial biodiversity and hence less number of cultures in our collections. Moreover, there is no school of taxonomy which does systematic capacity-building, looking to our future needs in various taxonomic groups of fungi. Restrictions on international collaborations through Biodiversity Acts have also affected the taxonomic studies.

Are we guarding our biodiversity without knowing what it contains? The same pathetic situation is also seen with other groups, i.e. bacteria, cyanobacteria, algae, lichens, etc. It is time to sanction projects to update our checklists, for mapping of microbial biodiversity, capacity-building and looking to future needs, restoration of herbaria, strengthening of culture collections and giving a free hand for microbial taxonomists for international collaboration.

A systematic planning and management may improve the poor state of microbial biodiversity. Almost every state in India has a State Science and Technology Council. The State Biodiversity Boards and Biotechnology Boards under State Governments, have university departments, many PG colleges with basic facilities and sophisticated instruments. Agencies like DBT, ICAR, ICMR, CSIR, DST, ICFRE and BSI/ZSI can launch joint efforts in the regions under their jurisdiction with institutions, universities and colleges with the available equipments and facilities. Each State Biodiversity Board and State Science and Technology Council should plan for systematic mapping of microbial biodiversity in a coordinated manner with a goal to inventorize, conserve and utilize the biodiversity in a sustainable manner. They should set up regional centres of culture collection well connected to the World Federation of Culture Collection (WFCC) as a network with the national culture collection centres. It requires

meticulous planning and cooperation among scientists, research scholars and college students, similar to the Costa Rican protocol[16] and Hawksworth's niches and habitats[17]. Recently, an outline of such a scheme for mapping and culture collection was presented to Madhya Pradesh Council of Science and Technology (MPCST), Bhopal (present author).

Basic concepts of taxonomy are not covered in schools, UG and even PG courses. Hence, capacity-building in taxonomy is difficult. Hence such concepts need to be introduced in schools, UG and PG courses with specialization in taxonomy.

Various agencies may derive benefits from the systematic mapping, and conservation of microbial biodiversity and culture collections. For example, ICAR can get novel biopesticides and biofertilizers of agriculturally important microorganisms; DBT can get novel fungi for their genetic manipulation; DST and CSIR can get secondary metabolites for industries, microbial germplasm for culture collection; UGC can use the students for field studies and motivate them towards research; ICMR can obtain knowledge about the distribution of human and animal pathogens in our terrestrial environments; BSI and ZSI can get information about fungi associated with threatened, vulnerable plants and animal/insect species – once the plant/animal species become extinct, the fungi associated with them will disappear without documentation. The obligate pathogens, biotrophs associated with plants, endemic plants and symbionts may be lost permanently[18]. Thus, all these agencies can benefit from their joint efforts in the national interest to save our microbial biodiversity.

People occupying leading positions in various agencies, must take the initiative to protect the national interests in mapping, cataloguing and conservation of bioresources and microbial biodiversity, before it is too late[19,20].

There is an urgent need to update our checklist of fungi and other microbes. We must also bring out a directory of specialists and taxonomists; as well as cataloguing of culture collections, initiation of monographic studies and their publication. Coordination of various agencies, manpower and facilities available at educational and research institutions across the country, as joint efforts for mapping biodiversity is a significant step in this regard. More bench-workers are needed. All efforts should be made to enrich culture collections through a network of various agencies involved in mapping and conservation.

Little time is left as urbanization, industrialization, deforestation, forest fire, floods, submersion of vast area, war and climate change are eroding our biodiversity and microbial diversity.

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