



# Strategies for Popularisation of Taxonomy in India

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## Abstract

Taxonomy provides a window to the broad understanding of biodiversity. While it is being increasingly recognized that taxonomy is the most important tool for identification and evaluation of living organisms, there is also a growing apprehension that interest in this important branch of science is rapidly declining. At a time when human-induced species extinctions far outnumber the natural processes, it would be a sorry state of affairs if species were to disappear even before they are discovered, named and classified. In the present-day scenario where students from institutions of higher learning evince only a modicum of interest in taxonomy and concomitantly these systems being able to produce far fewer schools of taxonomists, the task of reviving interest in taxonomy seems indeed daunting. Several measures are suggested herein to address this issue and some strategies proposed as part of the implementation of the Global Taxonomic Initiative in the Indian context.

**Keywords:** Botanical Illustration, Collaboration, Education, Popularisation, Taxonomy, Training

## Introduction

Linnaeus once wrote: “if you do not know the names of things, the knowledge of them is lost too” (*Nomina si nescis, perit et cognitio rerum*). This statement very succinctly tells about the value of names. Though we have been using names since the dawn of civilization Linnaeus brought order into the chaos and arranged living things in the proper perspective. True, every name carries a bit of information such as its unique characteristics, attributions, country and the people involved with it. We taxonomists are continuing this Linnaean legacy even after 260 years of its first proper usage and contributing to the science of taxonomy. As years pass by, we find that a generation of Indian taxonomists who contributed immensely in the post-independent India, had retired and there are no suitable replacements. This has impoverished our country in taxonomic expertise. Unless serious steps are taken at the national level to reverse the situation, soon we will reach a stage where we will be compelled to approach foreign botanists to identify common plants of our backyard at a heavy price.

## Background

The Convention on Biological Diversity (CBD) has recognized the existence of what is termed

the “taxonomic impediment”, a situation where there is dearth of taxonomic information, constraints within taxonomic institutions and gradual decline in taxonomic expertise across all biological groups, which is limiting the implementation of the Convention. As a natural corollary, this is a situation that is also viewed as an impediment to sound management of the world’s biological resources. In order to address this major problem the CBD has adopted the Global Taxonomic Initiative (GTI) by way of a work programme during COP 6 (2006) as a means for overcoming the “impediment” and facilitate good biodiversity management; the work programme was further supplemented after an in-depth review during COP 8 (March 2008). The GTI explores a number of cross-cutting issues including ways and means of addressing this “impediment”. One of the best ways is to popularize the subject at appropriate levels in the education systems, incorporating relevant topics in the school curricula. Equally important is the need to develop awareness of this subject and popularize it sufficiently so that people, particularly the younger generation, do not shy away from the subject. The need is to present/package it as a potential career option and, even otherwise, popularize it for the benefit of general public and furtherance of the science and its understanding.

In the Indian context, the Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) are the two main departments responsible for the survey, collections, maintenance/storage and systematic/taxonomic research including inventorying and monitoring. These departments also provide advisory service to the government and the public. There are several, R & D centres, national and state institutions of higher learning seriously carrying out biodiversity related studies and contributing to our knowledge on the rich bio-wealth of our country. There is an urgent need for a consolidation of efforts on the taxonomic front, prioritizing the activities in the short and long-term levels and setting targets to achieve in the next five years.

Herbarium specimens dating back to the 18<sup>th</sup> century to the present are housed in as many as 48 herbaria spread all over the country, including those of the Botanical Survey of India, which harbours the bulk of the country's rich heritage plant collections. The Central National Herbarium (CAL) of BSI houses about 2 million plant specimens, including 15,000 Type specimens. The 10 zonal herbaria together have more than 8,45,000 specimens representing the regional flora.

The ZSI has a rich repository of the national zoological collections, which are housed in its main museum at Calcutta. The museum at ZSI (headquarters) alone houses about a million collections representing 60,000 species. About 16,000 specimens are types. The ZSI also maintains galleries in its musea for education and research.

Together the BSI and ZSI along with other research institutes, including university departments and colleges across the country, hold a vast repository of biological collections that provide an ideal base for taxonomic research in India. There is also need to emphasize the value of the living collections maintained at the botanical and zoological gardens. The urgent need of the day is to popularize the study of taxonomy so that its significance in inventorying, monitoring, conservation and management of our biological resources becomes more widely known than it is today.

## Strategies for popularisation

The popularisation of taxonomy for according due cognizance of its significance in the day-to-day life of the common man and resource managers may be achieved through some short/medium term measures (Fig. 1) including:

- Training/education programmes
- Awareness programmes

- Schemes supporting taxonomic projects (floristic/revisionary studies)
- Supporting recovery/relocation programmes
- Research fellowship schemes
- Development of identification manuals
- Development of education material
- Organise exhibitions of botanical paintings
- Publication of topical coffee table books
- Gainful use of electronic/information technology medium

These need to be addressed with appropriate policy formulation, prioritization of feasible activities and expeditious implementation, with necessary budgetary provision built into the five-year/annual allocation of BSI/ZSI and all other research institutes and universities.

## Short and Medium Term Measures

1. **Specialist Training in taxonomy:** Recognizing the need for specialist training courses for students and teachers interested in taxonomy the two organizations need to establish a series of training/diploma courses. Identification of course objectives with development of course modules is essential while planning such courses. The training could be of immense use in the following conservation related exercises:
  - Floristic Inventories
  - Studies of Fragile Ecosystems
  - EIA Studies
  - Conservation of Endangered Species
  - Studies on Protected Areas
  - Conservation of Gene Pools in Botanic Gardens
  - Development of Herbaria
  - Studies in Biosystematics, etc.
- (i) *Basic level training:* One set of training could be for basic level for the students/forest officials/managers/community level participants in conservation-related activities, etc. These basic training courses, e.g., training in identification of native plants, must be aimed at enhancing capabilities of people and to develop expertise on identification and conservation

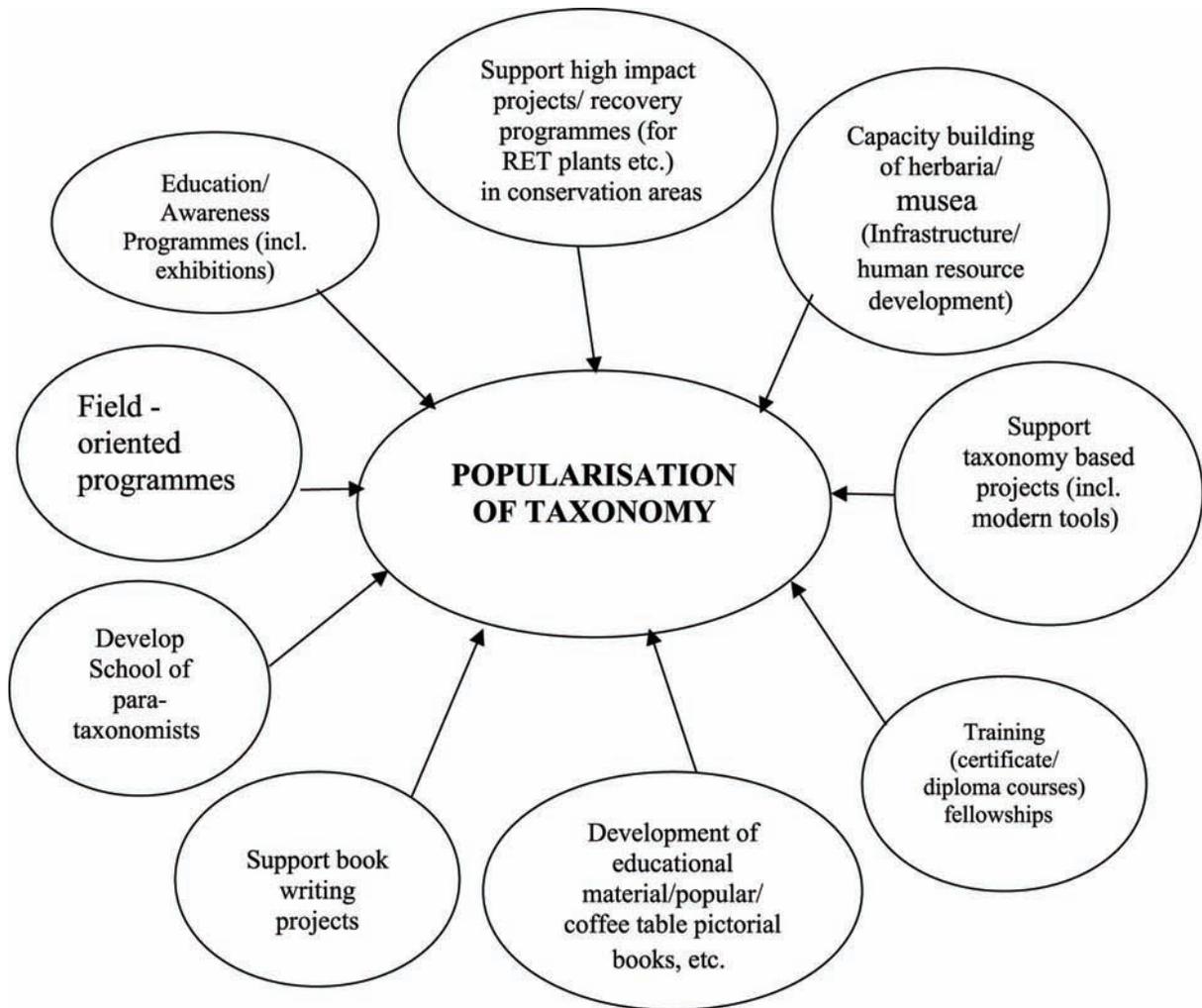


Fig. 1. Flowchart depicting the basic activities that would facilitate popularisation of taxonomy.

of biodiversity. These could be by way of Certificate courses of short duration primarily for para-taxonomists working for preparation of Biodiversity Registers, managers engaged in maintenance of parks, Wildlife Reserves, National Parks, Ecotourism Guides, etc. There is indeed a need for short training courses for 'para-taxonomists' to train them in the identification of important plants/ animals of their region. This would also facilitate identification of the threatened species in selected conservation areas or specific project areas. 'Para-taxonomists' would also be most useful for developing the Peoples Biodiversity Registers (PBRs) through which the initial documentation of the bioresources and their utilization is facilitated; there is clearly a need to validate the PBRs and this is where the hard-core trained taxonomists have a role to play.

Involvement of school teachers and students on collection and collation of taxonomic data is also very important for developing the next generation of taxonomists. In this context, an excellent example of scientists training school children in the Morton Arboretum, Illinois, USA, by way of developing local outreach collaborations through a long-term taxonomic project executed to study the genus *Carex* (<http://systematics.mortonarb.org/cariceae>) merits mention. The hands-on approach envisaged in the project helped students get involved in a taxonomic study on *Carex* generating original taxonomic data and insights; tested how well senior school students could collect detailed morphological data; increased their understanding of how taxonomic science is practised and; finally, increased their appreciation and understanding of taxonomy, biodiversity and evolutionary biology (Hahn *et al.*, 2016).

(ii) *Higher level training*: Courses can also be established for higher level students and M.Sc. degree holders who had a paper in the subject of taxonomy for their post-graduate course and who have an aptitude for taxonomy could be made eligible for admission to this course. The course may be conducted jointly by BSI, ZSI and other potential centres of learning. Experts on different groups of families may be invited as guest faculties from universities/colleges or other research institutes, if needed. A maintenance stipend may be given to the course participants. At the end of the course a "Certified Taxonomist" Diploma may be given to the successful participants. The Certified Taxonomist Diploma may be recommended as obligatory to certain management jobs, possibly even CITES Regulatory officials at Ports/Airports, etc. Within the taxonomic institutions, there is also an immediate need to have in-service training in taxonomy itself to strengthen the subject, with the application of modern taxonomic tools. This is need-based. Training in cognate disciplines is a later day need and must figure under the long-term goals. It is also imminent that over the years there would be a need for taxonomic institutions to diversify/integrate into relevant fields such as computer-aided cladistic analysis, molecular marker characterization, DNA fingerprinting, aspects of evolutionary biology, etc. The need for the furtherance of modern science in these institutes indeed demands diversification. Therefore, there is need to gradually build capacities in these disciplines within the taxonomic institutions of the country. This would help pave the way for diversification of their activities and allow them to keep pace with the modern scientific trends. Towards this end, there is an immediate need to develop infrastructure for setting up DNA lab., GIS lab., etc. Training needs should be assessed and then imparted accordingly.

The essentials of this training could include:

- *Familiarization of classics*: This is an essential prerequisite for becoming a good taxonomist and largely ignored in India. In olden times access to classics like the Linnaean publications was not that easy for every botanist. But nowadays, the internet facilities help us reach all the classics.
- *Acquirement of working knowledge of Latin*: Although the need for this is obviated by the new International Code of Botanical Nomenclature (ICBN), known as International Code of Nomenclature for algae, fungi and

plants (ICN), since 2011 (Melbourne Code), where the Latin diagnosis for description of new species published on or after 1 January 2012 is not mandatory, but only an option alternative to English. However, a working knowledge of Latin will help understand the classics and the protologues much better thereby helping understand the biological organisms much better.

- *Development of language skill for writing scientific papers*: This has to be carefully nurtured with a lot of exposure to different styles of writing to suit different journals. Honing of skills of botanists/taxonomists in writing of taxonomic accounts/ papers and floras leading to good publications is an important aspect of the training.
- *Plant descriptions*: The best way to describe plants in detail is to meticulously study the specimens. Special training should be given for describing plants afresh of different groups.
- *How to make good drawings and paintings to enhance the beauty and content of descriptions of novelties*: Use of microscopes for preparing sketches of the floral parts and other important features of plants must be taught along with a sketch of the habit in the best way possible. An important part of this training would be how to arrange the sketches thus made in to suitable format of the journal where it is to be printed; inking of assembled sketches using suitable Rotring pen of desired size; numbering and adding measurements to make it complete in all respects and then scanning the resultant artwork in high resolution. How to do botanical paintings as an art form must be also be taught, always emphasizing the need to ensure that the key features are reflected in the painting.
- *Use of good photographs*: Digital photographs help taxonomists record field data to a large extent these days; sharp images help make plates for publication, as per the requirement of the final printing size and the journal. Proficiency in the use of Photoshop is most useful for preparation of plates, and all students of taxonomy must be made familiar with this software.
- *How to design and print taxonomic outputs aesthetically*: This is a very creative area where all cannot contribute. The final output of this taxonomic exercise must be scientifically accurate and aesthetically

appealing which must even attract non-taxonomists. If we ourselves can not do this, hire some creative people to do it for us.

## 2. Revival of the art of botanical illustrations:

The art of botanical illustration was nurtured initially in Europe, thanks to the wealthy amateurs and the Royalty who had a great love for nature (Blunt, 1994), spreading subsequently to the colonies including India during the colonial period. William Roxburgh (1751–1815), the father of Indian botany, was much influenced by Koenig, a student of Linnaeus, who advised on the need for making life-size paintings of plants to supplement descriptions. This was during the 1780s when Roxburgh was in Madras and Koenig in the neighbouring Danish settlement in Tranquebar (Patrick Russell in Roxburgh (1795–98). Roxburgh very religiously followed this advice during the preparation of his *Plants of the Coast of Coromandel* (1795–1820) and *Flora Indica* (1820–1824). He commissioned native artists to undertake the job. This was continued when he took up the superintendence of Royal Botanic Gardens, Calcutta. The number of quality drawings and paintings done during that period utilizing Indian talent is a reflection of the importance given to this aspect of taxonomy (Fig. 2). Unfortunately, when BSI was reorganized, this good practice of making quality illustrations, which was in vogue during the British period, went into dismal neglect. A cursory study of the botanical drawings published from botanical gardens of Copenhagen, Edinburgh, Kew, Leiden, Paris, etc. shows that during the last 60 years there has been a qualitative improvement, with a certain expressive identity, which is a hallmark of the progress in this subject area (Dean, 2004; Magee, 2013; Sherwood & Rix, 2008). Several institutions in Europe and a few in South Asia sell replicas of botanical illustrations through their Nature Shops; this helps keep the public in touch with the beautiful wild plants and concomitantly, addresses the awareness programmes as well. Therefore, botanical illustrations indirectly help in the popularization of taxonomy. While on the other hand, during the same period in India, the art of botanical illustrations declined perceptibly, with amateurish drawings, which could be classified neither as art nor as science. This was a period of wanton neglect of an essential component of taxonomic studies. With the Indian culture being rich in the art in general, Indian botanists could have built upon

the initiative of the colonial period to establish a truly Indian identity in botanical art. However, late as it is, earnest efforts should now be made to revive this art and science at botanical gardens and institutions engaged in botanical research and train a series of artists and botanists alike to produce quality illustrations. A ray of hope in this period of darkness is the singular effort of a person through her Natural History School in Kalimpong where children are trained in botanical illustration. Ms Hemlata Pradhan of this school is an upcoming botanical artist herself having won many awards in Europe (Pradhan, 2008). Her training will certainly help many to come up in this field and contribute to the popularization of taxonomy through their paintings and scientific illustrations.

3. **Imparting knowledge of herbarium/museum techniques:** A course on herbarium/museum techniques would be essential for researchers and other conservation partners/managers. BSI and ZSI are well-placed to impart such training. The programme should ensure that trainees develop requisite technical skills in herbarium development, develop an appreciation of the information available in herbarium specimens for conservation, and gain insight to select/adopt methods most suitable to their own or sponsor's needs. The course module should include a wide range of useful aspects including an understanding of the role of taxonomy in conservation, collection (incl. ancillary collections, viz., carpological), specimen processing/ accessioning, mounting, arrangement, curatorial methods for special groups (viz., succulents and lower groups such as bryophytes and lichens), pest control treatments, etc.
4. **Research Fellowships:** Increase in the number of the Fellowships for research in the subject of taxonomy. Towards building capacity in taxonomy, the foremost task is to develop manpower with the basic ability to identify the name of the plants/animals in the field. Geographic representation of research scholars from gap areas may help survey these areas.
5. **Support for field-oriented taxonomic studies:** Research projects in DNA/chemical analyses, molecular taxonomy, mass propagation of already identified plants by tissue-culture methods/development of protocols for threatened plants, and other lab-oriented investigations should be considered under a different programme and not mixed up with



Fig. 2. a. Rheede's drawing of Tenga (HM 1: t. 1. 1678); b. Roxburgh's drawing of *Schrebera swietenoides*; c. Wallich's drawing of *Amherstia nobilis*; d. J.D. Hooker's *Rhododendron candelabrum*; e. Rungiah's drawing of *Clematis gouriana* Roxb. ex DC.; f. Royle's drawing in *Illustrations of Himalayan Plants*; g. Sreedharan Nair's drawing of *Huperzia phlegmaria* (L.) Rothm.; h. R. Vasudevan Nair's drawing of *Utricularia minutissima* Vahl and i. *Christisonia keralensis* Erady; j. P.C. Suresh Kumar's drawing of *Smithsonia viridiflora* (Dalzell) C.J. Saldanha; k. Meiko Ishikawa's painting of *Rafflesia pricei* Meijer; l. O.T. Ravindran's *Vanda tessellata* (Roxb.) Hook. ex G. Don; m. Hemlata Pradhan's paintings of *Paphiopedilum fairrieanum* (Lindl.) Stein; n. *Cymbidium lowianum* (Rchb.f.) Rchb.f. and o. *Renanthera imschootiana* Rolfe.

schemes aimed exclusively at promoting taxonomic studies with a strong field base. It may be appreciated that a field-oriented taxonomy project under the guidance of an expert PI is one of the most effective ways to train young field taxonomists.

6. **Support taxonomic facilities:** There is need to encourage the capacity building of Botanical/ Zoological Gardens, Herbaria, Arboreta, Aquaria, etc. in universities and colleges by providing technical and financial support. The only scheme to address the needs of capacity building in taxonomy is the All India Coordinated Project on Taxonomy (AICOPTAX) implemented by the Ministry of Environment and Forests (MoEF). This programme was launched in 1999, primarily to build capacity in the taxonomic institutes/universities for advancing the discipline, which is of cardinal importance for documentation of the country's biological resources, and fill in the identified gaps in the taxonomic knowledge base. The AICOPTAX scheme has helped the survey departments such as Botanical Survey of India and Zoological Survey of India and other institutes and universities to take up taxonomic work on algae, fungi, viruses, bacteria, archaea, bryophytes, lichens, pteridophytes, gymnosperms, palms, grasses, bamboos, orchids, helminths, nematodes, microlepidoptera and molluscs. The AICOPTAX scheme has also helped develop trained manpower to some extent.

7. **Use of e-medium and IT for taxonomy:** This being an age of information technology, taxonomic institutions need to capitalize on the capacities of the electronic medium to disseminate and widen the base of taxonomic knowledge. The potential taxonomic goods range from e-floras to identification manuals, area checklists, etc. Development of modules for cyber-taxonomy is work/man intensive task and would need coordinated efforts on the national front. This could be initiated through establishment of collaborative links with well-known IT departments. The attempt should be made to provide necessary taxonomic information online. Bringing online the information of specimen holdings of herbaria across the country by way of Indian Virtual Herbarium (IVH) is envisaged; this could at a later stage be linked to Global Biodiversity Information Facility (GBIF). Towards this end, there is an urgent need to computerise all major herbaria/musea, and build their capacities in terms of technical infrastructure to facilitate

digitisation of specimens, storage/archiving and transfer of electronic data, etc.

For the non-taxonomist or the uninitiated, the 'inconvenience' with taxonomic studies is often the continual changes in nomenclature. The frequent name changes for species are often perceived as an inconvenience by managers of botanic gardens also who are required to change the labels of plants in living collections and databases of the plant holdings. It may be appreciated that the very purpose of the science of taxonomy should not pose as a deterrent to take up the subject; names changes should be viewed as essential to lend clarity and validity to the process of naming plants. Over the years many genera/families are being continually subjected to nomenclatural changes owing to advances in molecular systematics and the greater credence being given to monophyletic groups/phyletic relationships. However, the significance of nomenclatural changes should not be lost on us and must be perceived as an essential component of the science of taxonomy in its pursuit of rectification and refinement, which is an essential tool for conservation and management. The recent researches/findings in molecular taxonomy are leading to mergers and splitting at both family and generic levels. The resultant changes in generic/family circumscriptions are reflected in different volumes of *The Families and Genera of Vascular Plants* (Kubitzki, 1990–), *Mabberley's Plant-Book* (Mabberley, 2017) and the umpteen e-floras and various taxonomic websites like APG (Angiosperm Phylogeny Group, 1998) and subsequent versions, *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II, III and IV* (2003, 2009, 2016). Students of botany more often than not find the transfer of some members of Asclepiadaceae into the family Apocynaceae or Sterculiaceae to Malvaceae, a tad perplexing, but need to accept the changes as part of the 'taxonomic conundrum'. In any case there are umpteen web-based taxonomic sites such as ePIC (Electronic Plant Information Centre, RBG, Kew), GRIN (Germplasm Resources Information Network), IPNI (International Plant Names Index), ITIS (Integrated Taxonomic Information System), Tropicos (Nomenclatural and Specimen Database of Missouri Botanical Garden), etc., that are useful for updating nomenclature.

8. **Human resource development:** The trained manpower that is derived from the AICOPTAX

scheme is a potential manpower source that is being underutilized. There is a need for policy intervention to make the best use of this trained manpower by way of roping in the trained taxonomists for strengthening the manpower of taxonomic institutes in India. It must be recognized that the present system of recruitment is weak in terms of getting in the best manpower trained in taxonomic work; other criteria dictate selections with the result that the survey organizations end up training these new recruits for the better part of their service period. At least a decade is lost before the newly recruited scientist becomes a good taxonomist! Many good universities have done yeoman services for the development of taxonomy in India such as Calicut University, Shivaji University, North-Eastern Hill University, Banaras Hindu University, Lucknow University, (bryophytes), etc. These universities have also developed schools of taxonomic expertise. Unfortunately, the job opportunities for this young generation of taxonomists are too low. There is an urgent need to address this issue.

9. **Popular book writing projects:** Encourage compilation and publication of popular books (as against technical) on common/rare/ endangered/ threatened plants and animals, for use of layman and college and school students. Small popular books, which are affordable, may be prepared on plants/animals belonging to special groups (e.g., medicinal plants, plants employed in religious rituals, aquatic plants, mangroves, birds, butterflies, fishes, insects, etc.) or occurring in particular areas (e.g., a village, a forest, botanical/zoological gardens, a sacred grove, a corporation area, lakes/river banks, etc.). Well-illustrated books of this kind will go a long way in creating an awareness about our rich biological wealth (based on their taxonomy), as has happened in many developed western countries like UK. Apart from English version, special effort may be made to publish such books in the local/ vernacular languages to make them accessible and useful to the local people, students and para-taxonomists. Such books prepared and printed with the governmental assistance may be sold at a subsidized price.

A book on *Indian Families of Flowering Plants* written in popular a style is indeed the need of the day. Therefore, a time-bound, result-oriented book writing project is proposed to be developed, primarily aimed at attracting potential students to

take up taxonomy as a career option. The project may envisage involvement of as many good taxonomists as possible with each one contributing at least one family treatment or two. For contributing to a family treatment, the contributor would be required to follow a prescribed format (uniform for all the families represented in India); provide up-to-date information in general and India in particular; comment on genera in the world, but focus more on Indian genera; provide illustrations of at least two interesting genera; provide colour pictures of all key features and mention the economic importance. These treatments could be critically edited and aesthetically laid out for a book by the end of a five-year period. This could serve as an encyclopedia, a ready reckoner and source book for further reference. Involvement and commitment of taxonomists from different regions is required to undertake the taxonomic treatments, with good artists preparing illustrations and professional photographers providing quality photographs.

### Role of Botanical Gardens in Popularisation of Taxonomy

Botanical gardens with their unique facilities traditionally engage themselves in several public oriented programmes apart from being the repository of living collections. Additionally, botanical gardens can help in dissemination of taxonomic knowledge by offering orientation programmes and refresher courses in taxonomy for various categories of target groups (Fig. 3).

With the general interest in taxonomy getting reduced in recent years there urgent need rekindling interest in the study of taxonomy so that its significance in inventorying, monitoring, conservation and management of our biological resources becomes more widely known. Dissemination of knowledge on plants to the common man may be achieved through some initiatives such as:

- Education programmes
- Nature trails
- Innovative display of live collections
- Development of simple identification manuals
- Development of education material
- Organise exhibitions of botanical paintings
- Distribution of pamphlets on local plants
- Recovery programmes with community involvement

The above activities can help generate interest in plant taxonomy. Some of these are elaborated below.



Fig. 3. a. Flower beds of Botanic Garden of Indian Republic (BGIR), Noida; b. Students at BGIR; c. Children on a drawing competition at BGIR; d. Dr. Michael Moeller (RBGE, UK) at the newly opened conservatory of rare plants at Calicut University; e. PG students at the Plant Science Festival, JNTBGRI; f. Visitors at JNTBGRI; g. Eco-Club students at the Orchidarium of JNTBGRI; h. Participants of Plant Wonders Programme; i. A tall girl reaches out to a *Nepenthes* pitcher; j. Dr. Jaspreet, Panjab University with *Nepenthes truncata*; k. Titan Arum, vegetative stage (*Amorphophallus titanum*) at Gurukula Botanical Sanctuary (GBS); l. Titan Arum in flowering at GBS.

**Education/Awareness Programmes:** Conducting exhibitions, seminars, essay and painting competitions for school/college students with the help of Nature Clubs and/or NGOs active in the field

is a very good way of disseminating knowledge on plants. Generating interest in taxonomy and creating awareness of its role in conservation could also be made through:

- Audio-visual shows
- Popular lectures
- Holding exhibitions of botanical paintings
- Distribution of attractive brochures
- Distribution of theme-based posters, etc.
- Dissemination of conservation messages (viz., greeting cards, pamphlets, etc.)

*Nature trails:* With the help of in-house experts/taxonomists, field trips/ camps may be conducted for school teachers and students to bring students and public closer to nature and make them aware of the local flora and to create awareness about the usefulness of the plants. These trips/camps may be for a single day or more. NGOs active in this field may also be involved/supported in these programmes. A boat trip along a river or a visit to a nearby forests, or desert could be conducted to observe and study various plants and animals there in different seasons. Making available well-illustrated books, as mentioned above, will enhance benefits from such trips/camps. Nature trails conducted for school children can have high educational value.

*Specialised plant collections:* Development of specialized/interesting collections of plants such as orchids, gingers, carnivorous plants, aquatic plants, cacti and succulents, etc. and their display with appropriate educational placards generate interest in the young minds and 'tickle their imagination' as it were. These collections exhibit the wonders of the plant kingdom and trigger interest in the minds of the young generation. Specialized collections such as cycads, carnivorous plants other botanical curiosities throw light on the evolutionary aspects of plants, bringing about an understanding of the subject. Although botanical gardens gather and maintain a wide variety of plants for display, education and conservation most gardens have one or two or more specialist collections for which they are noted. The Botanic Garden of Indian Republic (BGIR) at Noida-Delhi has indigenous trees of Indo-Gangetic region as its specialist collection. Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI), Thiruvanthapuram, has medicinal plants, bamboos and orchids as specialist collections while Gurukula Botanical Sanctuary (GBS), Wayanad, has all the endemics of southern India, with orchids, balsams, aroids and carnivorous plants included in its unique collection. Malabar Botanical Garden and Institute of Plant Sciences (MBGIPS), Kozhikode, houses all the water plants

of India. Such specialist collections need to be augmented. Curiosities such as the carnivorous plants serve to attract the attention of the public and tickle the imagination of the students.

*Recovery/Relocation programmes with community participation:* The threatened species need to be relocated/rehabilitated as part of any conservation programme of a major botanic garden. Plants identified by taxonomists as on the verge of extinction need to be mass propagated by appropriate methods for relocating them in their original localities and also for *ex situ* conservation in other botanic gardens. Appropriate cultivation techniques need to be adopted or species-specific protocols developed on a case to case basis. Relocation projects need to be undertaken with the full participation of local communities for better management and monitoring of relocated populations. Education (pictorial) material should be prepared especially for local communities in vernacular languages to facilitate their participation in the conservation programmes.

Botanic gardens under R&D institutes and university systems have an advantage as they are repositories of live plants for demonstration purposes. Therefore, these botanic gardens can play an important role in the dissemination of knowledge on plants and generate public interesting the subject. Recognizing the importance of education in conservation science, an integrated education programme needs to be developed. Educational programmes of botanic gardens have an immense scope and potential for targeting large student groups, particularly in metro cities. Educational programmes must also be designed for other sections of the society, including the physically challenged and the rural communities. The initiatives of botanic gardens must include establishment of linkages with schools and colleges; involvement of the rural communities; designing of education programmes, with focus on endangered plants, medicinal plants under threat of exploitation and plants of ethnobotanical use; and development of resource material including publications, pamphlets/leaflets/brochures on specific conservation issues. Botanic gardens also need to impart necessary training to teachers, foresters, gardeners, etc.; specialised courses in arboriculture and herbarium techniques should also be planned. A modern Interpretation Centre is desirable for educating the visitors on plant diversity and the need for conservation.

Gardens also need to provide recreation in an aesthetic manner by way of delivery of societal benefit so that learning becomes a fun process, particularly for the younger generation.

## Actions for next Fifty Years

*Completion of Flora of India project through collaborative approach:* The expected output of scientific work over the next fifty years needs to be identified and prioritized. The primary mandate of inventorying the flora through the ongoing “Flora of India” project should be expedited. It must be appreciated that this onerous task cannot be completed without sufficient manpower. As such, human resource development in the area of taxonomic expertise must be developed on priority basis. Towards this end, there is an urgent need for filling up all the vacant posts in BSI/ZSI. Once this is achieved there would be a need to allot specific work to specific scientists and do not divert them to other programmes before the allotted work in this regard is completed. To avoid inordinate delay in execution of revisionary/monographic works, there is need to fix timelines while assigning taxonomic projects to individual scientists in the manner followed at Kew herbarium. If necessary, specific aspects of the work may be allocated to other experts/taxonomists working in other institutions, universities and colleges by way of collaborations. There are good numbers of taxonomic investigators working outside the ambit of AICOPTAX, or without any financial support. There is a need for BSI and ZSI to send out messages to the effect that (i) the concerned national organisations are keen to recognise the taxonomic work of the investigators and (ii) the organisations are genuinely interested in adding the type material to their collections. These are days of collaborative research and there is need to move away from ‘working in isolation’.

In this context, albeit a slight digression, the deposition of type specimens is an issue that needs to be addressed in accordance with the Melbourne Code (McNeill *et al.*, 2012), which requires the type material be deposited in a public herbarium, and the clause under Section 39(3) of Biodiversity Act (2002) which states that ‘any new taxa described by any person shall be notified to the repositories or any institution designated for this purpose and he/she shall deposit the voucher specimen with such repository/institute’. An announcement about this should be placed in reputed journals exclusively devoted to taxonomy such as *Nelumbo* (formerly *Bulletin of the Botanical Survey of India*), *Rheedeia*, etc. For various reasons, papers describing new taxa are also being published in other journals such as *Journal of the Bombay Natural History Society*, *Indian Forester*, *Indian Journal Forest*, *Journal of Economic and Taxonomic Botany* in India and *Blumea*, *Kew Bulletin*

*Reinwardtia, Taiwan* elsewhere. There are many instances where the type material is not deposited in the herbaria where it is supposed to have been deposited as per the claim in the paper published. The journals publishing new species may consider a policy to have a certification from the herbarium where the type specimens are claimed to have been deposited in the manuscript before accepting it for publication.

*Adoption of modern tools:* There is a need to refurbish taxonomic studies in India through the adoption of modern methodologies such as computer-aided cladistic analysis, biotechnology tools, molecular marker characterization/analysis and application and DNA fingerprinting for integration with relevant fields such as evolutionary biology and phylogeny. The science of taxonomy practised at present in India is clearly lagging behind in adoption of modern tools such as cladistics for interpretation. There is an urgent need for addressing this issue.

*Development of plant diversity portal for India:* Target 1 of the Global Strategy for Plant Conservation (GSPC, 2015) calls for an online flora of all known plants by 2020. While this herculean task of producing a widely accessible list of known plant species as the step towards a complete world flora in the present-day scenario, where the number of taxonomists are dwindling, there is need to create an e-portal to capture all the existing taxonomic data on a portal, if we are to contribute meaningfully to the World Flora Online (WFO) project (WFO, 2016), which was launched in India during COP 11 of the Convention on Biological Diversity during October 2012. In the Indian context, there is a need for such a portal to be hosted by the National Informatics Centre (NIC) or the ENVIS centres of BSI and ZSI, with taxonomic expertise drawn widely from the survey organisations (BSI/ZSI) as well as the universities and institutions dealing with life sciences. The aggregator portal approach detailed for the Flora of South Africa (Le Raux *et al.* 2017) is worth considering/replicating; the approach describes a methodology wherein all the scattered floristic/taxonomic literature/ information is collated, converted and captured into electronic form and aggregated into a single portal for compilation of an e-flora.

It is quite clear that what we need in the country today is a paradigm shift in our approach to practice the science of taxonomy, either by way of basic research or towards its practical application, in aspects of conservation and management of our biological resources.

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