Scientists are moving ahead to create a living cell. The bonding of a variety of biomolecules with metallic nanoparticles/quantum dots has opened up a new frontier in biomedical sciences. Self-assembly techniques through controlled nucleation and growth, pen and rubber stamp lithography of nano-materials, and bioprinting of cells are some exciting developments for creating new and functionalized living and non-living materials.

Nanotechnology will continue to be pursued vigorously for discovering new phenomena, for developing new/tailored/functionalized high-performance materials and for economy-driven applications in the more practical and useful form of thin films. Nano-electronics and nano-photonics will continue to lead the pack by creating new frontiers driven by the economic forces of the information technology industry. Perhaps the most significant and singular contribution of nanotechnology is the convergence between the various sciences and engineering disciplines. Thus, life scientists are now happily shaking collaborative hands with physicists, chemists, materials scientists and engineers in developing new inter-disciplinary areas of medical science and technology, bio-fuels and bio-agri technologies that are expected to have an impact on the health and welfare, energy and food security of mankind.

Concluding remarks

Hype creates mirages. Hope leads to reality. Any realistic and significant research and development in these new frontiers can only be achieved by well-endowed, critically sized groups of dedicated scientists and engineers working in an ecosystem that ensures autonomy with accountability for outcomes, competitiveness and a liberal academia–industry interface for entrepreneurship. If we fail this time in India, as we have done in some other nationally coordinated projects, our nanotechnology will become 'na-no technology'.

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Plant biodiversity conservation and role of botanists

V. A. Bapat, G. B. Dixit and S. R. Yadav

It is a well-known fact, that worldwide thousands of plant species are endangered and facing extinction with the current trend of their exploitation and destruction[1,2]. In recent years, there is a growing awareness concerning the impact of temperature rise, industrialization, desertification and shift in the growing seasons of plants, loss of pollinators, seed dispersers and increasing frequency of intense weather events such as drought, storms and floods making several valuable plants extinct[3,4]. According to the International Union of Conservation of Nature (IUCN), it is estimated that the current species extinction rate is between 1000 and 10,000 times higher than it would naturally be. It is acknowledged that the future survival of humanity depends on the conservation and protection of natural wealth, and destruction of a species or a genetic line symbolizes the loss of a unique resource. This type of genetic and environmental impoverishment is irreversible. Changes in the structure in the multiplicity of resources lessen the society's scope to respond to new problems and opportunities, and there is the danger of new plant diseases or pests, climatic change due to the greenhouse effect and other setbacks. To overcome these hurdles, there is a need of coordinated efforts of scientists, government departments and nongovernmental organizations to undertake effective measures for conservation of plants (Figure 1). Methods to support conservation consisting of education, providing enticements and adding capacity building need to be adopted at the earliest. To avoid the loss of biodiversity the government authorities have formulated stringent rules to safeguard and protect the existing biodiversity, ensuing protection of the present natural assets. This guided enactment of the Biological Diversity Act for India controls access to all genetic resources of the country and includes provision for equitable profit-sharing. The detailed specific rules are available on the webpage of the Ministry of Environment and Forests, Government of India, and the National Biodiversity Authority, a statutory and regulatory body established under Biological Diversity Act, 2002 (www.nbaindia.org). IUCN and other organizations undertake wide ranging research projects on the status of biodiversity to protect specific species, manage and restore national parks, botanical gardens[5] and other protected areas, and promote the sustainable uses of natural resources[6,7]. The modus operandi of biodiversity conservation, however, has to be implemented considering not only protection of any plant life in its natural status but its further multiplication and subsequent plantation followed by utilization which have other economic reflections[8]. Considering the new concept of bio-power applied to numerous crops, fruit and plantation crops as well as forest trees, saving of endangered plants has to focus on their further utility, if any, for various benefits to civilization. In this context, the role of a botanist assumes prime significance to undertake a particular project on

threatened plants. The tasks of a botanist can be broadly divided as: (i) Identification and characterization of an endangered plant. (ii) Study of taxonomy, ecology and physiology. (iii) To understand the reasons for a particular plant becoming endangered. (iv) Propagation of the plant under controlled environment followed by *in situ* and *ex situ* conservation. (v) To create a self-sustainable population of threatened species in their natural habitat. (vi) Compilation of database and documentation of all threatened plants. (vii) To explore the utility of an endangered plant, if any, for basic as well as commercial applicability. (viii) Use of molecular markers and molecular diagnostic tools to give valuable support for the rapid and accurate identification of plant species through DNA bar-coding[9].

Considering the tasks outlined here, recent assessment projects provide important lessons learnt and demonstrate that plant conservation can be achieved in a timely manner with sufficient training and human resource. The success of each project depends upon the formation of a network of local botanists with expertise on both the species themselves and threats to their habitats[10]. Authorities capable of validating the assessments, formulating regional plant conservation strategies and ultimately making recommendations to both governmental and non-governmental organizations are directed to mitigate the loss of plant diversity. National herbaria provide most of local botanists with regional assessment networks, creating the necessary bridge between taxonomic collections and conservation, particularly for a group of plants in which many species are 'known' only in the herbarium.

Against this background, the aims of biodiversity conservation are to maintain the current level of biodiversity as well as to stop any further decline. Hence, a distinction has to be made between a wrongful exploitation of a particular species purely for commercial gains, without giving any attention to the continued existence of the exploited species, and a botanist who wishes to protect and rescue the plant from disappearance. The authorized botanist has to be allowed to bring the endangered plant to his work place and study the various aspects as listed earlier. Assessment of the work of a plant scientist can be made during a specific period and, if found satisfactory, he may be encouraged further. Implementation of the Biodiversity Act becomes a stumbling block for a plant scientist to pursue his research; he must have open and free access to the plant source. A botanist considers grassroot programmes, aimed at educating rural farmers and urban consumers, while also providing technical guidance to regional and national governments in the development of natural resource policies. Several rare plants have been successfully rescued and established, and the micropropagation technology has helped save numerous rare plants such as *Ceropegia fantastica*[11], *Huernia hystrix*[12], *Daphne cneorum*[13], *Frerea indica*[14], *Coronopus navastii*[15] and others[3]. Taking into account the contribution of a plant scientist, creating a barrier for a botanist to undertake any work on endangered plants will simply defeat the main purpose of biodiversity conservation. There is no second opinion concerning banning of unrestricted cutting and harvesting of valuable germplasm only for monetary benefits. A balanced and judicious biodiversity conservation programme is necessary taking into consideration a botanist predicament and problems.

The most effective conservation programmes generally involve institutions with long-term commitment to a particular region becoming increasingly well adapted to the constraints of the local, cultural and political environment. The research centres having an impressive record of accomplishment with their natural, long-term commitment to the maintenance of living collections and overall plant diversity have an institutional mandate for stability and conservation. The safeguarding of biodiversity is expected to permit such research institutions to have a free access to collect

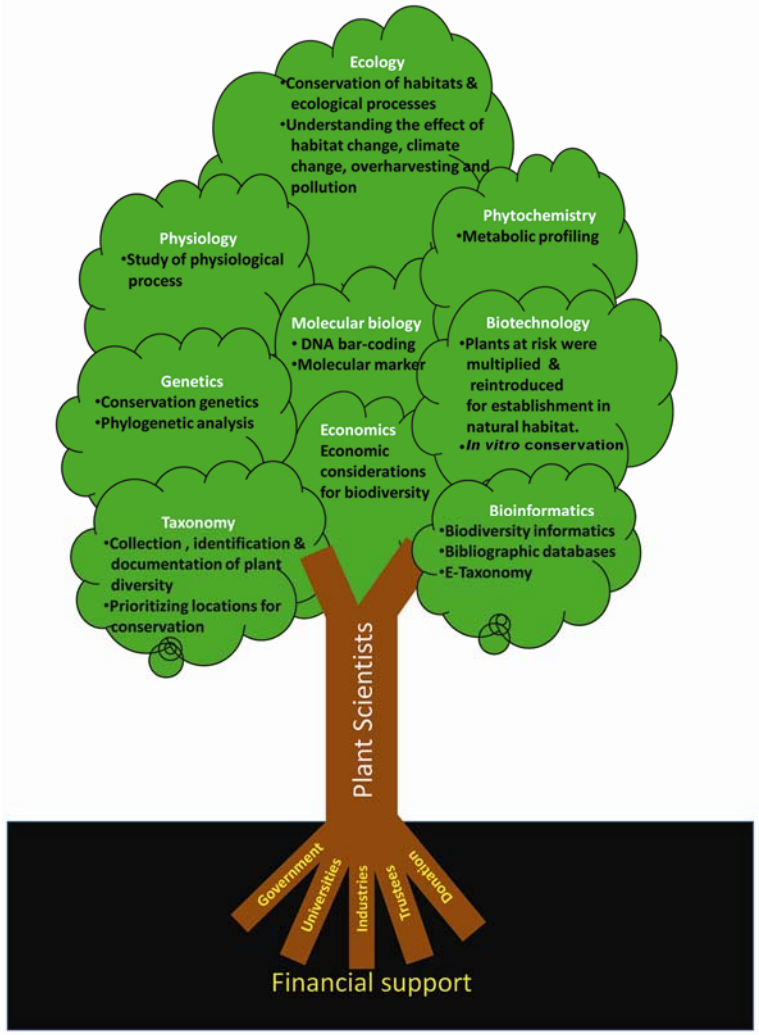

Figure 1. Priority research areas of plant conservation and other related controlling factors for biodiversity.

Table 1. Major research institutes in India working on conversation of plant biodiversity

Ashoka Trust for Research in Ecology and the Environment, Bangalore
Botanical Survey of India and its institutes in different parts of the country
Bombay Natural History Society, Mumbai
Central Institute of Medicinal and Aromatic Plants, Lucknow
Department of Botany, Shivaji University, Kolhapur
Forest Research Institute, Dehradun and State Forest Departments
Institute of Himalayan Bioresource Technology, Palampur
M.S. Swaminathan Research Foundation, Chennai
National Botanical Research Institute, Lucknow
National Bureau of Plant Genetic Resources, New Delhi
National-Level Mangrove Research Institute, Sunderbans
Tropical Botanical Garden and Research Institute, Thiruvananthapuram
Yamuna and Aravalli Biodiversity Park, New Delhi
Central Arid Zone Research Institute, Jodhpur

the research material of endangered plants. This will help create the best conditions for plant systems to survive through the creation of regional networks of corridors, close technical integration with rural farmers, and educational and policy outreach to the general public and government officials. In India, several research institutions are doing commendable work for plant biodiversity conservation (Table 1).

It has become clear that the mission to protect plant diversity is more demanding than has been anticipated. This is because of a better understanding of the impacts of climate change. Also, it is recognized that the complexities of conservation biology will require a multitude of different approaches to be applied to achieve the conservation of such a wide diversity of plant species and ecosystems. Sustaining and building on that momentum and enthusiasm will be one of the key factors in assuring its success during the coming decade[16].

Rapid progress in biological sciences and instrumentation for scientific data has widened the role of a botanist considerably. The term 'botanist' may have to be expanded since molecular biologists[9], geneticists[17], biochemists, a forester[18] or a bioinformatics expert could also play a vital role in biodiversity conservation in a broader perspective. For example, advancement in molecular diagnostics provides the opportunity to survey deeply and accurately the identification of a species as well as predict the history and relationship between different evolutionary lineages[19]. Hence, thinking across knowledge systems with an open view concerning bridging the gaps in biological sciences will enhance our accumulation of knowledge for an effective conservation strategy. Additionally, integration of the understanding from various disciplines of biology will hasten the process of conservation considerably and effectively. A particular endangered plant may be a cereal, a legume, a fruit plant, or an ornamental flowering plant or even a tree, and depending upon the type of the plant, a botanist has to plan his conservation strategy with help from other biologists. For the beginning of any conservation, a plant scientist has to study sources and priorities of a particular plant material followed by methods of collection and sampling of the collected material. Another task for a botanist is to decide between *in situ* and *ex situ* conservation of a particular species. Some rare plants may not survive in *ex situ* environment, but will grow well in *in situ* location, and vice versa. However, a majority of the plants, conserved so far have shown the ability to grow both *in situ* and *ex situ* surroundings. Several options under *ex situ* conservation are available, such as botanical gardens[5], seed banks[20], orchards, tissue culture[3] or cryopreservation[21], and depending upon the plant system, a researcher has to select a cost-effective and appropriate plan. *Ex situ* conservation procedures have an imperative role in the protection of rare plants and are a source of fundamental research, education and publicity. Simultaneously, they offer to supply plant propagules to return to the wild as part of any future recovery endeavours. However, a botanist has to avoid unwanted hybridization and genetic drift events between a rescued plant and its surrounding allied species in the environment.

In situ conservation has certain constraints of regular monitoring, difficult access to the location or a danger of destruction from wild animals or birds. However, this does not undervalue the significance of *in situ* conservation. It is essential to decide methods for *in situ* conservation from habitat management to direct manipulation of the populations. Planting of rescued plant material in natural habitat is done either by sowing of seeds or through vegetative propugules depending on the plant system. It has to be kept in mind that the selected protected area will cover only a small portion of total diversity of a rescued rare plant. Hence several areas will have to be conserved for a single species under *in situ* conservation. Sometimes the job of a scientist becomes difficult during *in situ* conservation because certain plant members belong to the intricate ecosystem – moist tropical forest trees, which are mutually dependent for survival; plants with high dormancy that cannot be broken by conventional techniques, or plants having specialized breeding systems. Recently, a combination of *ex situ* and *in situ* conservation methods of a critically endangered plant (*Ceropegia fantastica* Sedgw.) has been demonstrated[11]. Against this backdrop, a well-judged decision has to be taken by a botanist between *ex situ* and *in situ* conservation. Additionally, patents and intellectual property rights are significant mechanisms of conserving biodiversity, and it is necessary for a scientist to ensure that patents support the aims of biodiversity conservation and its sustainable use[22].

Botanists have a crucial role to play in conservation, bio-prospecting and sustainable utilization of plant diversity because they know about the plants, their distribution, status, importance, species that need immediate measures and methods of conservation. Although conservation of RET species is a difficult task, but it is not impossible and many plant species can be conserved with human inputs. If all the botanists of the country contribute to understanding the causes for their rarity, constraints in reproduction, ecology, propagation and development of nursery techniques for RET species, most of the species can be successfully conserved. Only botanists can generate baseline data crucial for conservation. Collaborative efforts and cooperation among government, policy makers, funding agencies, society and botanists is the need of the hour for plant conservation especially RET species (Figure 2).

Figure 2. Some rare endangered and threatened plant species from Western Ghats.

Lastly, a new entrant to the science of biodiversity has to work in the rapidly changing scenario of modern-age technologies, patent and intellectual property rights, though he/she may have different mindset and approaches to conserve the precious gifts of nature. The idea of conservation, although basic priorities remain unchanged, will be having wide and effective strategies.

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ACKNOWLEDGEMENTS. V.A.B. thanks CSIR, New Delhi for Emeritus Scientist fellowship. We thank Mr Umesh Jagtap, for helping with the illustration.

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