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Article *in* Current science · February 2018

DOI: 10.18520/cs/v114/i03/512-518

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Contributions of plant taxonomy, herbarium and field germplasm bank to conservation of threatened plants: case studies from the Himalayas and Eastern and Western Ghats

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Conservation of biodiversity, a growing concern today, faces multiple challenges. Although ecosystem approach has been recommended as a solution, conservation of threatened species is difficult as they are spread across the ecosystems and are often restricted to microhabitats. In this article, the importance of taxonomy, herbarium and field germplasm bank in conservation of threatened species is discussed. It is concluded that individually each of these measures has important role to play in conservation. They also complement each other in reversing the threat perspective of the species.

Keywords: Biodiversity, conservation, germplasm bank, herbarium, taxonomy.

Introduction

BIODIVERSITY conservation, a global necessity, faces multi-pronged challenges that needs to be resolved[1]. The magnitude of the problem is increasing as evident from the growing list of threatened species. The challenges posed by environmental change and threats from accelerated rates of extinction call for increased attention to conservation of biodiversity[2]. Global estimates indicate that we have discovered and named only 80%–90% of the flowering plants[3]. The angiosperms are represented by 18,159 species, of which 6,200 belonging to 141 genera under 47 families are endemic to India. Irwin and Narasimhan[4] have recorded 49 genera endemic to India that belong to 22 families. Out of 141 endemic genera in India, about 114 are monotypic. About 28% of the total Indian flora and about 33% of angiosperms occurring in India are endemic[5]. It is estimated that about 10% of flowering plant species in India are threatened and 34 plant species have been reported to be extinct[6].

Although conservation of threatened species using ecosystem approach has been advocated[1], it would be practically difficult as these species are spread across the ecosystems and are often restricted to microhabitats. Hence, addressing conservation of these species is difficult and prioritization becomes an inevitable requirement[7]. Unfortunately, our understanding on these species in general, and their population, biology and taxonomy in particular, is extremely limited[7]. Herbaria play a paramount role in resolving the taxonomic conflicts among the threatened species. In addition, it provides detailed information on the distribution range of the species and often areas of occupancy. These information are critical for prioritizing the threatened species for conservation. Though the best possible option is *in situ* conservation, it is often not enough while dealing with highly threatened or critically endangered species with miniscule population. Therefore, *ex situ* conservation is warranted in most cases. Germplasm banks play an important role in the conservation of some of the most threatened species. In India, there has been an increase in germplasm holdings native to introduced species at different centres of National Buraeu of Plant Genetic Resources (NBPGR), other natio-

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nal institutions and university botanic gardens. With this background, the role of taxonomy, herbarium and germplasm in the conservation of phytodiversity have been discussed in this article.

Taxonomy

India is geographically located at the junction of three major biogeographic realms, viz. Indo-Malayan, Eurasian and Afro-tropical. With a land frontier of about 15,200 km, and a coastline of 7,516 km it is the seventh largest country in the world and the second largest in Asia. India is considered as one of the 12 centres of origin for several plant species in the world[8]. It is also an important centre of agro-diversity having contributed 167 species to the world agriculture and is homeland for 320 species of wild relatives of crops. India accounts for 8% of the global biodiversity existing in only 2.4% land area of the world[9]. In the present state of our knowledge, India has 47,791 species of plants already identified and classified, yet there are many to be identified and described. There is an increasing trend of interest in taxonomic research in recent years, especially in the field of the lower plant groups where maximum new discoveries are being made. Certain phytogeographic regions such as Eastern Ghats and coastal regions, which were thought to be well explored, are now providing interesting new discoveries of flowering plants[10]. This emphasizes the growing need of taxonomic exploration in the country.

Floristic diversity

The flora of India is both rich and diverse due to a wide range of variation in climate, altitude and ecological habitats. The distribution of number of Indian plants under different groups are, angiosperms (18,159), gymnosperms (77), pteridophytes (1,274), bryophytes (2,531), lichens (2,434), fungi (14,936), algae (7,309) and virus/bacteria (1,071), all of which account for about 11.4% of the total plant species of the world. About 28% of the Indian plants are endemic to the country. The richness and endemism in Indian flora are mainly concentrated in four hotspots of floristic diversity, viz. the Himalayas, Western Ghats (and Sri Lanka), North East India and Andaman Islands (Indo-Burma) and Nicobar Islands (Sundaland), out of the total 34 'global biodiversity hotspots'[11].

The relevance of taxonomy in conservation is vital as the basic step in the conservation action begins with correct identity of the species concerned. Taxonomic understanding resolves much of the ambiguity and mistakes in identification as well as conservation needs of such species. This is obvious from the current nomenclature status of many Indian species. While working with the flora of Meghalaya, it was realized that names of several plants were changed and different from those mentioned in previous floras[12,13]. In many of the databases created at different centres, details are stored under names recognized earlier, even though, based on current taxonomic understanding, they are known by new names. This makes it inevitable that application of comprehensive taxonomic knowledge is an essential first step towards conservation efforts. This could happen even in family circumscription as seen in the case of *Embelia ribes*, placed in Primulaceae in recent times, whereas all Indian floras treated it under the family Myrsinaceae[14]. Taxonomic complexity prevailing in terms of species, their synonyms and their phytogeographical distribution is immense. This will be clear if we look at the species of *Embelia* or *Stereospermum*[14], where there exist several resembling species and ambiguity in identification. Similarly, majority of the names appearing in *Flora of Assam* have now been changed[13,15,16]. This creates a situation where the information tagged to a botanical name lies scattered and spread across several locations, against several names, even though the species in question remains the same. This also makes it difficult to collate information, unless the taxonomy is resolved. A classic example in this respect is of *Aquilaria malaccensis*, earlier treated as *A. agallocha* in *Flora of Assam*. So is the case with *Taxus wallichiana* which is also known as *Taxus baccata* or *Taxus baccata* var. *wallichiana*. In some instances, the species *Kydia glbrescence* is often treated as *K. calycina*, thereby missing the due attention that it warrants, especially in forestry programmes. A few other examples are *Schima khasiana* treated as *S. wallichii* and *Panax pseudoginseng* and *P. sikkimensis* treated under *P. wangianus*[17]. Extensive work on *Panax* brought out the issues concerning the taxonomy of this genus[18–20] and highlighted the diversity and distribution. An interesting case is that of *Entada purseatha*, which is also referred under the names *E. phasioloides* and *E. scandens*. Similarly, a great deal of confusion exists in the case of *Gnetum scandens* or *Gnetum ula*. In these cases, the required action becomes evasive and diluted due to nomenclatural confusions. A clear and crisp understanding of taxonomy can only resolve such issues. This will also help in pooling information, which is widely scattered and chronicled, thereby having a better perception on taxonomy of the species and comprehensive action for the shortlisted species. A correct application of International Code of Botanical Nomenclature (ICBN) and the issues related to generic transfer of a species[21], revealed that in the case of *Delonix* and *Poinceana*, or the more common *Poinsettia pulcherrima* and *Euphorbia pulcherrima*, and also in use of names like *Arundinaria*, *Schizostachyum*, *Flickingeria*, *Persea* and several others, a in-depth taxonomic knowledge can empower the researchers to take informed action and acceptance of specific names.

An understanding of these names along with their taxonomic status often results in better perception of global presence and threat status. This will also highlight the requirement of local action as well as collection of information on related taxa. This is due to enhanced perception of endemicity and distribution patterns. For example, *Coptis teeta* is regarded as an endemic plant in Arunachal Pradesh[22], but its relative *C. teeta* var. *Chinensis* or *C. teetoides*, which is found in China, creates ambiguity on the endemicity of the species. Had it been worked out well the researchers could have taken a cognitive view on the geographical coverage of the species.

Certain groups of plants like orchids, rattans and bamboos have several issues related to their identity. However, excellent taxonomic studies on them have helped resolve such problems and resulted in monographical works[23–27]. Taxonomic work on *Calamus inermis* helped realize its current status of distribution and the necessity of appropriate actions for conservation[28]. Similar is the case with another important group of plants, the rhododendrons, which are confined to the higher hills in India[29]. There are a large number of new taxa, either as new species or as subspecies or varieties that are being added from the Himalaya. Due to various reasons, quite a few of these taxa are under threatened category. Similar studies have helped several conservation efforts in the Eastern Ghats. Balsams, belonging to the genus *Impatiens*, form a single group with the largest number of endemic species in the country, but have evaded the attention of taxonomists in the country. A recent work brought to light several species of *Impatiens* as threatened species for immediate action on their conservation[30]. Plants like *Odisha cleistantha*, *Lasiococca comberi* and *Cycus sphaerica* could be brought under conservation studies due to the efforts of Panda *et al.*[31,32]. It is pertinent to note that the works mentioned above as case studies point out to the relevance and significance of taxonomic studies in conservation. In fact, several of these species have been taken up for conservation studies under the support from Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India. The role of correct taxonomic identification of the species is extremely important while prioritizing the species for conservation. An example of such prioritization exercise where correct taxonomic identification is the key was undertaken to finalize the species for conservation studies and actions for the above mentioned DBT initiative (Table 1)[33].

Taxonomic perceptions also help in the elucidation of relationships and to arrive at the possible research requirements based on better biological understanding, drawing one's attention to floral biology, reproductive biology or genetical requirements based on phylogenetic findings. Further, in recent times, many types of reproductive data such as floral morphology, floral nectars and fragrances, pollinators, phenology, breeding systems and dispersal mechanisms have been utilized effectively in plant taxonomy[34].

Herbarium

In classical taxonomic research, the founding pillar is the herbarium. The herbarium specimens provide the foundation for nomenclature, the basis for identification, the common reference for communication and the vouchers for floras and bio-systematic studies. They also throw light on the ecology and population status of the species in question, as detailed information is well documented and stored in the field labels and notes attached to the specimen. We incidentally have herbarium sheets dating back to centuries, providing information from that period[35]. Herbarium collections also provide a wealth of information on our natural heritage, which extends back to hundreds of years. Thus, they provide the only reliable and verifiable record of the changes to our flora during the expansion of human population. Jain and Rao[35] discuss details of preparation of a complete herbarium specimen. The herbarium also provides us with the ecosystem specifics and thereby helps us decide the ecological requirements of the species. Herbarium resource contributes valuable information for identifying seed-collecting localities and must be treated as an important tool in biological research leading to conservation of plant diversity[36]. An added advantage is in the form of seeds in herbaria getting germinated, bringing back the bygone plants into the world. They also offer the scope for comparative analysis of morphology and inter- and intra-species relationships, along with phenological and morphological inputs. All fields of biological science, from the level of molecular biology to ecosystem science, are dependent on collections, not just for application of names, but as the referencing point of study in all aspects of biodiversity. Thus, the herbaria are a versatile encyclopaedia for plant biology, which can help reverse the trend of threats by appropriate conservation measures. The field notes attached to the herbarium specimens indicate the location, association, bio-cultural information covering the local names, utilization aspects, if any, phenological information, distribution and abundance, all of which are essential for developing a perspective plan for conservation. The herbaria also promote interdisciplinary research with their allied facilities and have the capability of forming viable networks for global conservation. The herbarium specimens indeed are the voucher sheets for clarifying data related to threats and conservation, and most importantly, the botanical identity. Thus, it is an important tool in taxonomic studies which can even be performed for ages. Needless to mention, it is imperative to have herbarium collection of all those species in question under any life science research projects, especially those dealing with biodiversity conservation. Further, such specimens can also provide resource for future molecular works leading to confirmation of their identity and phylogeny. In most herbaria there are also ancillary

Table 1. Prioritization exercise conducted for the nationally coordinated project under the Department of Biotechnology, Government of India in 2011–12 for finalizing the species to be taken up for conservation studies and actions implicating the importance of taxonomic nomenclature

Species	State	Priority		Zone	Habit
Acer hookerii Miq.	Sikkim	2		Temperate	Tree
Aconitum heterophyllum Wall. ex Royle	Himachal Pradesh	1		Alpine	Herb
Aconitum nagarum Stapf	Manipur		2	Temperate	Herb
Amentotaxu sassamicus D.K. Ferguson	Arunachal Pradesh	1	1	Subtropical	Gymnosperm
Angiopteri sevecta (G. Forst.) Hoffm	Meghalaya	2	1	Tropical	Fern/shrub
Angelica glauca Edgew.	Uttarakhand	1		Alpine	Herb
Arnebia euchroma (Royle) I. M. Johnst	Himachal Pradesh	2		Alpine	Herb
Bambusa nagalandiana H.B. Naithani	Nagaland	3		Subtropical	Bamboo
Berberis manipurana Ahrendt	Manipur	3		Temperate	Shrub
Biermannia jainiana S.N. Hegde & A. N. Rao	Arunachal Pradesh		1	Subtropical	Orchid
Brucea mollis Wall. ex Kurz	Assam		2	Tropical	Tree
Calamus acanthospathus Griff.	Mizoram	2		Tropical	Palm climber
Calamus innermis T. Anderson	Sikkim	1		Tropical	Palm climber
Calanthe wightii Rchb.f	Sikkim		2	Subtropical	Orchid
Cinnamomum cacharensis R. Parker	Assam		2	Tropical	Tree
Citrus macroptera Montrouz	Assam	3		Tropical	Tree
Coptis teeta Wall.	Arunachal Pradesh	3		Temperate	Herb
Cycus sphaerica Roxb.	Odisha	3		Tropical	Gymnosperm
Cymbidium wightii King & Prantl.	Sikkim		2	Subtropical	Orchid
Cyathia spinulosa Wall. ex Hook	Meghalaya	2		Tropical	Fern/tree
Dipcadi concanense (Dalzell) Baker	Maharashtra	1		Tropical	Bulbous herb
Dactylorhiza hatagirea (D.Don) Soó	Uttarakhand	1		Alpine	Orchid
Decalepis hamiltonii Wight & Arn.	Karnataka	1		Tropical	Climber
Dendrocalamus brandisii (Munro) Kurz	Nagaland	1		Tropical	Bamboo
Dendroboium nobile Lindl.	Arunachal Pradesh		1	Subtropical	Orchid
Dipcadi goaense Prabhu. *et al.*	Goa	1		Tropical	Bulbous herb
Ephedra gerardiana	Uttarakhand		1	Alpine	Herb
Elaeocarpus sphaericus (Gaertn.) K. Schum.	Assam	1		Tropical	Tree
Embelia ribes Burm.f.	Meghalaya	1	1	Subtropical	Climber
Flickingeria fugax (Rchb.f.) Seidenf	Arunachal Pradesh	2		Tropical	Orchid
Gentiana kurroa Royle	Himachal Pradesh	1		Alpine	Herb
Goniothalamus simonsii Hook.f. & Thomson	Assam	3		Tropical	Tree
Gymnadenia orchidis Lindl.	Arunachal Pradesh		2	Alpine	Orchid
Gymnocladus assamicus P.C. Kanjilal	Arunachal Pradesh	1		Subtropical	Shrub
Gynocardia odorata R.Br	Tripura	1		Tropical	Tree
Hydnocarpus kurzii (King) Warb	Tripura	1		Tropical	Tree
Hypericum perforatum L	Himachal Pradesh		2	Subtropical	Herb
Ilex venulosa Hook.f.	Meghalaya		1	Subtropical	Tree
Impatiens clavata Bhaskar	Karnataka		1	Tropical	Epiphytic Herb
Impatiens talbotii Hook.f.	Goa and Karnataka		2	Tropical	Herb
Kayea assamica King & Prain	Assam		1	Tropical	Tree
Lagerstromia minuticarpa Debb. ex P.C. Kanjilal	Sikkim	1		Tropical	Tree
Lasiococca comberi Haines	Orissa		2	Subtropical	Shrub
Lilium polyphyllum D.Don	Uttarakhand	2		Subtropical	Herb
Odisha cleistantha S. Misra	Orissa		2	Tropical	Shrub
Ormosia robusta Baker	Assam		1	Tropical	Tree
Madhuca insignis (Radlk.) H.J. Lam	Karnataka		1	Tropical	Tree
Malaxis acuminata (Lindl.) Kuntze	Uttarakhand	1			Orchid
Paphiopedilum druryi (Bedd.) Stein	Kerala		1	Tropical	Orchid
Paphiopedilum venestum (Wall. ex Sims) Pfitzer	Arunachal Pradesh	2		Subtropical	Orchid
Paphiopedilum villosum (Lindl.) Stein	Mizoram	2		Subtropical	Orchid
Paris polyphylla Sm.	Manipur	1		Subtropical	Herb
Picrorhiza kurroa Royle ex Benth.	Himachal Pradesh	1		Alpine	Herb
Pittosporum eriocarpum Royle	Uttarakhand		2	Subtropical	Shrub
Podophyllum hexandrum Royle	Himachal Pradesh	1		Temperate	Herb
Rheum australe D. Don	Uttarakhand	1		Alpine	Herb
Rhododendron subansiriense D.F. Chamb. & Cox	Arunachal Pradesh		2	Temperate	Shrub
Rhododendron wattii Cowan	Arunachal Pradesh		1	Temperate	Shrub
Skimmia laureola (DC.) Siebold & Z ucc. exWalp.	Uttarakhand	1		Subtropical	Tree
Smilax glabra Roxb.	Arunachal Pradesh	2		Tropical	Climber
Swertia chirayita (Roxb.) Buch.-Ham. ex C.B. Clarke	Himachal Pradesh	1		Temperate	Herb
Trichopus zeylanicus (Gaertn.) Thwaites	Kerala		1	Tropical	Herb
Vanda bicolor Griff.	Nagaland	2		Subtropical	Orchid
Vanda stangeana Rchb.f.	Arunachal Pradesh		2	Subtropical	Orchid
Vanilla pilifera Holttum	Assam	2		Tropical	Orchid

The figures under the column priority: 1 – High priority, 2 – Medium priority, 3 – Low priority.

facilities like a museum, laboratory for investigation and library that help in further research.

Thus, from a conservation perspective, it can be seen that herbarium specimens can indicate the conservation status. In fact, the earlier threat assessments carried out in India are based on extensive herbarium studies. The *Red Data Book of Indian Plants*[6] is the outcome of such efforts based on herbarium studies. It throws much light on endemism, and phytogeographic preferences of any given plant. To a certain extent, it also indicates the rarity and decline of a population. Many of the earlier publications on conservation did depend to a large extent on herbarium information[6,7,26,37–40]. Several conservation assessment and management prioritization (CAMP) efforts in the country have inputs from herbaria. In this regard, all CAMP workshops organized by Foundation for Revitalisation of Local Health Traditions (FRLHT) have drawn basic inputs from the herbarium data and associated field works[41]. CAMP efforts have resulted in categorizing threatened medicinal plants in accordance with IUCN threat categories. It has also resulted in publications dealing with threatened species[42] that helped species like *Madhuca insignis* to the forefront of conservation action through research projects[43]. The network of 112 Medicinal Plant Conservation Areas (MPCAs) in India, covering 13 states and representing most of the phytogeographic zones, is the result of CAMP workshops conducted by FRLHT. The taxon sheets generated through CAMP exercise have a large share of information from herbarium specimens and associated field works. Having recognized the threat status, further research and conservation actions are designed that include *ex situ* actions like germplasm banks (GPBs), multiplication efforts and sustainable use[44,45].

Germplasm banks

GPBs are live storehouses of variations and positive traits identified by researchers for which they are nurtured. The germplasms are selected through a meticulous process of survey and search, and then harnessing the propagation material to establish the germplasm with desired traits in a designated GPB[46]. The extensive passport data associated with each collection are a veritable databank of the species' life history and information. Started originally as a part of the agricultural and horticultural endeavour, it is ideally employed in forestry and in the conservation sector. GPBs were established in the country during 1950s with the sole purpose of conservation of agricultural crops, which later changed to conservation and utilization[47]. GPBs are usually used for seed collection and cryopreservation. These are augmented with field GPBs. Organizations like National Bureau of Plant Genetic Resources (NBPGR), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Council for Scientific and Industrial Research (CSIR) institutions, e.g. National Botanical Research Institute (NBRI) and Institute of Himalayan Bioresource Technology (IHBT), Indian Council for Forestry Research Education (ICFRE) institutions, Botanical Survey of India (BSI), Indian Council for Agricultural Research (ICAR) and several botanical gardens and research institutions including Regional Plant Resources Centre (RPRC), Bhubaneswar are engaged in conserving germplasm across the country at national, regional or state level. Many of the GPBs act as valuable refuge for our threatened plants. Since the germplasms are gathered from different sources of existing populations, they capture the diversity at different levels with a range of adaptive genetic make-up. GPBs make it easy to access plant propagation material that otherwise would have to be fetched from far away locations. In fact, many researchers, especially those dealing with propagation and genetic improvement, rely on the germplasm sources of the above-mentioned institutions for obtaining material for their work. In a nutshell, GPBs are reservoirs of diverse germplasms facilitating access to different stakeholders for propagation of desired quality planting materials as well as parental lines for genetic improvement of different crops. There are volumes of literature available on establishment and conservation of genetic diversity[48]. Some of the efforts to establish germplasm in forestry sector include, State Forest Research Institute (SFRI), Itanagar and Indian Council of Forestry Research and Education (ICFRE) institutions where several threatened species such as *Canarium strictum*, *Morus laevigata*, *Aquilaria malaccensis* and *Taxus wallichiana* are conserved. These are models for conservation of some of our threatened plants[49]. These GPBs, as they harness and harbour diversity, act as pools of variation and help species gain hybrid vigour, which will empower them to face survival challenges.

A germplasm of threatened plants can, thus, provide a valuable source of propagation material for augmenting the resource in the field[50]. This assemblage being in a convenient location could facilitate easy dissemination ensuring wider dispersal[51,52].

GPBs play a vital role in getting the resource material pooled together to a single location where it can be grown. Considering the several forest types occurring in the country[53], based on altitude preference, there may be a need for several GPBs scattered over different agro-climatic zones at different altitudes. Certainly a tropical plant may not be suitable for growth in a temperate or alpine site, and vice versa. This will also warrant consolidated information strategy and action for conservation of our genetic resources[48].

International treaties such as Trade-Related Aspects of Intellectual Property Rights (TRIPS) dealing with the rights over natural resources including Convention on Biological Diversity (CBD) emphasize the need of GPBs for effective access and benefit sharing[47]. The National Biodiversity Authority of India too highlights the importance of germplasm in conservation and natural resource utilization.

The GPBs not only offer resource material, but also provide scope to conduct performance trials and conservation biology-related research. This can facilitate development of protocols for cultivation and rehabilitation of species facing extinction. A classic example can be seen in the case of rattans[26,27,54]. The germplasm banks of rattans provide an assured source of propagation material, act as refuges for threatened species, aid in conservation research and action, and foster awareness about our threatened plants.

A pertinent example would be the GPBs maintained at SFRI, Itanagar[50]. The orchid germplasm has several threatened species such as *Dendrobium nobile*, *Pahiopedilum faireanum*, *Vanda coerulea* and *Reinanthera imshootiana*. Similarly, the bamboo germplasm shelters a great diversity of bamboos that include *Dendrocalamus giganteus*, *Schizostachyum pergracile*, etc. In the germplasm on rattans, there are several threatened species such as *Plectocomia assamica*, *Calamus gracilis*, *Calamus mastersii* and *Demonorops jenkinsiana*, which are otherwise hard to find in abundance in nature. *Aquilaria malaccensis*, which is one of the most threatened plants in north-eastern India, is cultivated in Arunachal Pradesh. Similarly, *Taxus wallichiana* is being grown at Bomdila, Arunachal Pradesh. Planting materials are supplied from here to other forest divisions for plantation. Materials are also exchanged with other research organizations, especially the forest research institutes, thereby offering a true conservation scope.

Conclusion

Taxonomy, herbarium and GPB play an important role in conservation. Each one of these is significant in its own respect. Though all these are connected, individually they contribute to reversing the threat perspective. In any case, a deeper understanding of each is essential for effective conservation of the threatened species. Although they are capable of individual contribution, they also complement each other.

The herbarium can provide data over time and space. Much new (undescribed) diversity has also been reported to be present in existing herbarium collections[55]. With appropriate modifications in the collected data, they can become strong tools in working out distribution, eco-restoration and augment research capabilities of several organizations through technical networking. This will also empower taxonomic analysis and bring in clarity for species delimitation and inter-specific relations. The taxonomic knowledge, thus gained, can contribute to threat assessments and management prioritization for evolving conservation management plans. Conservation plans to rescue and rehabilitate plants on the verge of extinction will warrant *ex situ* tools to augment the *in situ* efforts. GPBs are ideal solutions in such difficult situations to provide refuge to intra-specific variations too. They can contribute significantly to resource augmentation and promote cultivation prospects. Several GPBs established across different phyto-geographic zones and agro-climatic locations can cater to the entire country effectively, through which we can hope for the survival of our vanishing species. With wider distribution of species, it is often imperative that the different R&D establishments join hands and work together as a network. However, this will warrant more liberal funding and focused research, and adequate capacity building and awareness creation. There may also be a need to recognize Centres of Excellence at strategic locations in different zones. Institutions engaged in plant genetic resource management need to focus on taxonomic research related to species of Indian origin, or where diverse materials have been introduced to the gene banks.

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ACKNOWLEDGEMENTS. We thank Prof. C. R. Babu, Prof. R. Uma Shaanker, Prof. L. M. S. Palni, Dr K. S. Charak, Dr Mohd. Aslam and Dr Onkar Tiwari for encouragement and support; and Dr M. Sanjappa, Prof. Darshan Shanker for fruitful interactions. We also thank the officers in charge of several herbaria in India for permission to visit and consult them; the Director, SFRI and the Forest Department, Arunachal Pradesh for support. We also acknowledge DBT, New Delhi for providing financial assistance (Project No. BT/Env/BC/01/2010).

doi: 10.18520/cs/v114/i03/512-518