Conservation implications of plant endemism in high-altitude Himalaya*

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This paper analyses the nature and extent of information available on various aspects of plant endemism in the Himalaya. The study reveals that high-altitude Himalaya is rich in plant endemic diversity and temperate families show higher than expected level of endemicity. As elsewhere, the endemic species mostly occupy drier habitats, especially in the alpine zone. Among endemics, cytogeographic studies reveal that schizoendemics constitute the largest group. However, these findings are contrary to the arguments, which relate endemism with polyploidy. The paper discusses conservation implications of high plant species endemism to (i) determine extension of boundaries of existing protected areas (PAs) or establishment of new PAs, (ii) identify appropriate sites for establishing trans-frontier parks, (iii) focus on recognizing relative importance of economic and conservation value of anthropogenic endemics and (iv) recognize the consequences of expected low genetic diversity of narrow endemics. An approach for prioritizing strategies for action is proposed, which is based on three important attributes, viz. geographic range, ecological amplitude and anthropogenic pressure. Through this approach, a particular attribute of an endemic taxon calls for a specific action. Besides, the approach highlights the importance of involving indigenous communities, traditional institutions and NGOs to complement efforts of academics, scientists and government departments to ensure conservation and utilization of this resource.

MOST of the publications on Himalayan biodiversity dwell on analysis of existing status of plants and animals, focusing on medicinal, aromatic, edible, fuel and fodder plants; assessment of structure, composition and recruitment trends of biotic components of selected communities, factors responsible for biodiversity loss and the implications thereof, etc.[1–8]. An action plan setting priorities and targets has been published recently[9]. Besides, biodiversity-related issues have been, and are being, addressed in various meetings, seminars, workshops, symposia, etc. The frequency of such events has progressively increased, particularly during the last decade or so. All these activities have largely been mobilized and promoted by the commitments covered in the Convention on Biological Diversity. To some extent, the data generated as a result of the above activities have built up a useful baseline information (Table 1). Notwithstanding these initiatives, wide gaps in knowledge exist. Among others, systematic investigation on plant endemic diversity is one of the most important issues of concern. Inventorization, assessment and maintenance of endemic plant diversity can help to promote representativeness, naturalness, uniqueness, and high-use value of biodiversity elements. This paper focuses on (i) the extent of available knowledge on plant endemism, with special reference to high-altitude zone and gaps therein, (ii) conservation implications and (iii) an approach for prioritizing actions for conservation.

High-altitude Himalaya

High-altitude Himalaya is variously defined and described. It is considered a hyperoptimal extreme above the forest line[10], characterized by cold and arid climate[11] with rich and varied biotic potential[12]. Since this paper focuses on distribution pattern of floristic elements of high-altitude Himalaya, the present analysis considers vegetational composition as an appropriate indicator for delineating the high-altitude zone. The vegetation patterns change sharply at the upper (cool) temperate region all across the Himalaya. Shifts in compositional pattern in this zone indicate that conifer, mixed, broad-leaf communities (*Salix, Aesculus, Abies* and *Pinus*) are replaced by pure conifer stands (*Cedrus, Taxus, Abies*) in parts of trans and northwest Himalaya; mixed broad-leaf (*Aesculus, Fraxinus, Rhododendron* and *Quercus*) by evergreen oak and conifers (*Quercus semecarpifolia, Pinus* and *Abies*) in the west Himalaya and mixed broad-leaf (*Alnus, Michelia, Castanopsis* and *Litsea*) by oak lauraceous and conifers (*Quercus lamellosa, Abies* and *Tsuga*) in central and east Himalaya.

High-altitude Himalaya is reported to show decline in tree-species richness, total tree density, basal area and

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Table 1. Representativeness of Himalayan plant biodiversity – an overview

Level	Representativeness		Reference
	Himalaya (% of India)	High-altitude Himalaya (% of Himalaya)	
Eco-regions	16 (NA)	09 (56)	60
Communities			
Vegetation types	21 (NA)	08 (39)	61
Forest types	10 (26.0)	07 (44)	62
Forest formations	11 (NA)	03 (25.4)	1
Species			
Angiosperms	8000 (47)	NA	28
Gymnosperms	44 (81)	NA	28
Pteridophytes	600 (59)	NA	28
Bryophytes	1737 (61)	NA	28
Lichens	1159 (59)	NA	28
Fungi	6900 (53)	NA	28
Special groups			
Medicinal	1748 (23)	525 (30)	35
Wild edible	675 (67)	175 (26)	33
Trees	723 (28)	87	63

NA, Information not available.

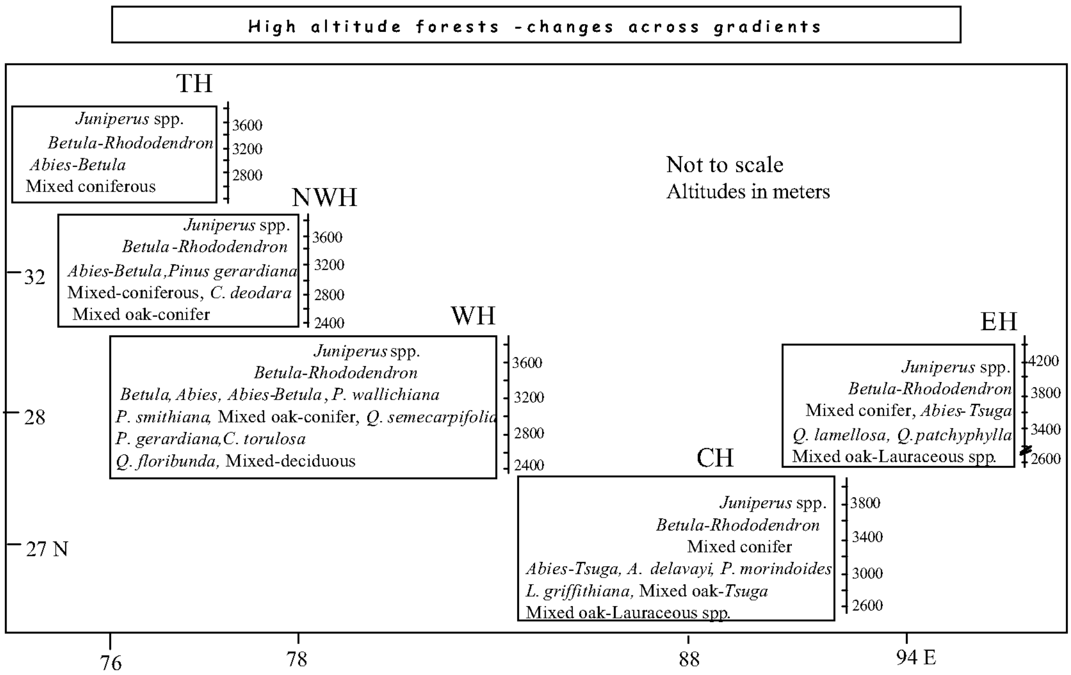

Figure 1. Spatial pattern of distribution (along altitude and latitude) of dominant plant communities in the Himalaya.

primary productivity[13]. The zone is, however, rich in representative (native) and endemic biodiversity elements[14–16]. This is revealed even among dominant elements, both along altitude and latitude (Figure 1). Moreover, the zone harbours fragile habitats, which are subject to various intensities of anthropogenic pressure.

Endemism

The word endemic is used to denote any taxonomic category restricted to a particular biogeographic unit[16]. Studies on endemics are useful to (i) understand past vegetational history[17], (ii) identify taxonomic relationships[18], (iii) characterize floristic regions[19], (iv) determine optimal design of conservation units[20] and (v) prioritize conservation strategies[21,22].

The classification of endemic into 'mega' and 'micro' was once held most objective: the former grouped as 'good species' or supraspecific taxa, while the latter included only intraspecific taxa. Subsequently, endemics were grouped into palaeo – representing relicts or systematically isolated taxa having no close relationship (tree ferns, *Ginkgo biloba*, etc.) and neo endemic – as newly evolved, phylogenetically closely related taxa (e.g. species of *Impatiens, Primula, Gentiana,* etc.).

A compendium of Himalayan biotic endemism is not available. Himalayan plant endemics are, however, well marked at the species and subspecies level, for example, species and subspecies of aconitums, saxifrages, gentians, primulas, balsams, etc. The only treatise on the extent of plant endemism in the Indian subcontinent[23] puts on record 41.5% of dicot species endemic to India with highest concentration in the Himalaya (28.8%). The reasons put forth for rich endemic plant diversity in the region includes: gamopetalous nature, zygomorphic floral structure, low regeneration capacity, geographic isolation, etc. Subsequent studies report (i) 150 genera endemic to Indian floristic region (including peninsular India, Himalayan flanks and Sri Lanka)[24], (ii) 164 genera in the same region (including Burma)[25], and (iii) 141 genera exclusively within India, in which 111 are monotypic. Of these, 68 are restricted to the Himalaya (40 in the east, 11 in the west and 17 throughout the Himalaya)[26]. A conservative estimate suggests that over 3000 dicot and 1000 monocot species are reported to be endemic to the Himalaya[27].

Major contributions on Himalayan plant endemism include reports from Kashmir[16,17] and entire Indian Himalaya[3,28]. Besides, a systematic analysis of endemic plant diversity of different families of the Indian Himalaya has been documented (Ranunculaceae[29], Brassicaceae[30], Primitive families[15], Caryophyllaceae[31]). These studies have revealed two possible centres of endemic plant diversity in the Himalaya (trans/northwest and central/east Himalaya). In the Himalayan context, plant endemism was used as an important tool for determining priority conservation sites[22] and species[32] in timberline zone of west Himalaya. Analysis of endemism in wild edible[33,34] and medicinal plants[35,36] of the Himalaya has also been reported (Table 2).

In spite of the fact that endemic plant diversity of the Himalaya is, in most cases, higher than the neighbouring mountain regions (Table 3), the subject matter has not been studied intensively. For example, even a complete list of plant endemics of the Himalaya is not available. Therefore, the present analysis and interpretation is largely based on the work undertaken in Kashmir and the recent studies on distribution of endemic plants in several plant families of the Himalaya.

Plant endemism at high-altitude

Available information in temperate families reveals that in most cases, endemism at high-altitude (alpine–subalpine zone) is higher compared to estimates of entire Himalaya (Figure 2). This feature is particularly prominent in trans/northwest and west Himalaya[15,29,30], suggesting thereby that high-altitude zone can be considered as one of the endemic centres.

Endemics are generally concentrated in a limited number of taxa and are taxonomically not a random assemblage[37,38]. This is because different taxa respond differently to the processes like speciation, hybridization, immigration and extinction[37]. Himalayan endemic taxa also follow a non-random pattern. Among the families investigated for index of endemicity (Ic), the tropical families did not exceed the expected level of endemism by global standards in the Himalaya. How-

Table 2. Himalayan endemism – reported features

Features	Endemic % or no	Reference
Endemic diversity centres		
East Himalaya	–	64
Two possible centres (T/NWH & EH)	–	34
High generic endemism		
Indian floristic region	150 genera	24
	164	25
India	141	26
Himalaya	68	26
High specific endemism		
Himalayan plants	28.8%	23
Angiosperms	40.0%	28
Gymnosperms	16.0%	28
Pteridophytes	25.0%	28
Bryophytes	32.0%	28

EH, East Himalaya; T/NWH, Trans/North-West Himalaya.

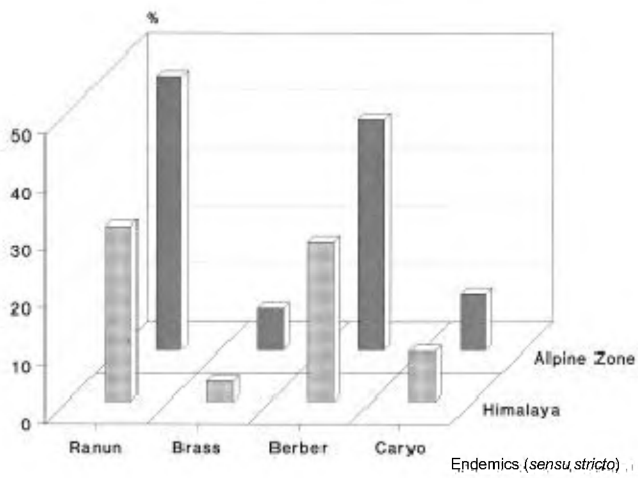

Figure 2. Extent of plant endemism at high-altitudes in some temperate families in Indian Himalaya.

Table 3. Species richness and endemism in Indian Himalaya and neighbouring mountain regions

Mountain range	Area (10^3 km^2)	Taxa	Endemic taxa (%)	Reference
Tien-Shan Alai	180	6525	3370 (51.6)	65
W. Tien-Shan	45	2812	358 (12.8)	65
N. Tien-Shan	NA	2500	225 (9.0)	65
Caucasus	65	6350	1600 (25.2)	65
NW Caucasus	1	819	287 (35.1)	65
Alps	110	1049	331 (31.0)	43
Balkan Mts	110	1193	404 (33.9)	43
Pamir	25	700	32 (4.6)	65
Kazakhstan	2500	4750	550 (11.6)	66
Indian Himalaya	439	8000	3200 (40.0)	28

NA, information not available.

ever, Berberidaceae (temperate), Magnoliaceae and Scizandraceae (discontinuous) showed significantly higher than the expected level of endemicity[15]. Likewise, several taxa show relative richness in endemism (e.g. Ranunculaceae: *Delphinium, Ranunculus, Aconitum*; Berberidaceae: *Berberis*).

Considering both biogeographic provinces and elevation zones, endemics in Himalayan families follow specific pattern of distribution. For example, Ranunculaceae, Brassicaceae, Berberidaceae and Caryophyllaceae are endemic-rich at higher elevations of trans/northwest and west Himalaya. In the mountains, increase in per cent endemism is reported to increase with altitude up to subalpine zone[37]. However, Himalayan temperate families investigated so far suggest that high endemism prevails even up to the high alpine zone. Further, floristic endemism in a representative high-altitude area (the timberline zone) of west Himalaya has revealed considerably high proportion (51.3%) of endemics[22,32].

Likewise, in Kashmir Himalaya (covering an area of over 222,800 km^2), a representative choria of Great Himalayan Range, also shows similar trend in plant endemism. Of the total 3054 angiosperm taxa (belonging to 872 genera), 967 (31.7%) are endemic. Among these, 363 (11.9%) are short range (SR) and 604 (19.8%) broad range (BR) endemic taxa (Table 4). Moreover, families with higher incidence of endemism are richly represented at high-altitude. The dominant high-altitude genera rich in endemic species include *Astragalus* (53: 33.96%), *Potentilla* (45: 37.77%), *Nepeta* (37: 56.75%), *Saussurea* (35: 74.28%), *Taraxacum* (70: 80.25%), *Gentiana* (37: 40.54%), *Pedicularis* (31: 64.51%), etc.

Based on the data of narrow endemics (dicots) of Kashmir Himalaya ($n = 333$), the altitudinal distribution reveals their maximum representation in alpine (67.6%) followed by temperate alpine (21.6%) and subtropical/temperate (16.8%). Their life-form distribution suggests that herbs are better represented than shrubs.

Table 4. Extent of plant endemism in Kashmir Himalaya

Plant group	Total taxa	SR endemic (%)	BR endemic (%)	Total (%)
Dicotyledons	2403	333 (13.9)	518 (21.6)	851 (35.4)
Monocotyledons	651	30 (04.6)	86 (13.2)	116 (17.8)
Total	3054	363 (11.9)	604 (19.8)	967 (31.7)

Source: ref. 17; SR, Short range; BR, Broad range.

Habitats and endemism

Endemics are known to occupy a range of habitats. However, their occurrence is associated with rocky cliffs and rapidly eroding sites in most of the mountain systems[37]. The plant communities on such sites are reported to resist changes in local climate. In the present analysis, endemics were analysed on the basis of decreasing level of moisture from marsh to sandy/arid soils. Interestingly, it revealed that most of the narrow endemics occupy the drier habitats. This relationship is more prominent in alpine endemics (Figure 3). Similar trends of distribution are reported in southeast France, with majority of endemic species occupying communities with high stress level; rocky xerophyllous grasslands, screes, cliffs and rock habitat[39]. The present habitat relationship of endemics is a reflection of the dominating Mediterranean climate in trans/northwest Himalaya[15,16,40].

Ploidy and endemism

Ploidy level has been used to trace the genesis of plant endemism. For example, it has been reported that relicts (palaeo endemics) have high chromosome number and are assumed to be ancient polyploids. Likewise, ploidy levels reflect direction of range expansion in some species. It is in this context that post-glacial history of several endemics of Scandinavian species has been traced using polyploidy levels[41]. These assumptions gained momentum through the classification of endemics on the basis of ploidy level[42] into (i) palaeo (polyploids whose ancestors are extinct or unknown), (ii) patro (diploid whose polyploid derivatives have wide range), (iii) apo (polyploid derivatives from widespread diploid) and (iv) schizo (retaining same ploidy level as their progenitor). Palaeo and patro are considered old relicts of Engler, whereas apo and schizo are young. Genesis of the floristic elements is therefore traced through this classification. In mountain floras of Europe[43], flora of California[44,45] and some other highlands of the Mediterranean, the above categories have been used to discuss endemism. However, due to lack of adequate cytological data, wider use of this classification has not been possible in most of the regions across the world including the Himalaya.

In India, cytogeographic studies[46–51] on *Rhododendron, Camelia, Magnolia, Buddleia*, etc. reveal that northeastern Himalaya and southeastern provinces of China are very active and highly diversified, floristically and phytogeographically. These areas are reported[4] to possess diploids with very wide range followed progressively by smaller range of polyploids. It is also stated that higher ploids are essentially endemics confined to narrow ranges. This does not, however, hold true for the entire Himalayan range considering the following investigations.

Investigations on chromosome counts of restricted species (and their wide relatives) are available for 64 taxa (51 dicots and 13 monocots) in Kashmir Himalaya. The analysis reveals that diploids (45, 70.3%) are more than the polyploids (19, 29.7%). Ploidy level ranges from $2x$'s ($2n = 3x = 42$) in *Phlomis bracteosa* Royle ex Benth. to $12x$'s ($2n = 12x = 60$) in *Senecio jacquemontianus* (Dcne.) Benth. ex Hook. f. Schizoendemic constituted the largest group (46, 71.8%) followed by schizo/patro (8, 12.5%), patro (5, 7.8%), schizo/apo (4, 6.4%) and apo (1, 1.5%). Therefore, barring a few relatively old 'scizo/patro' endemic taxa (*Trollius acaulis, Paeonia emodi, Parrotiopsis jacquemontiana, Viburnum foetens*, etc.), schizo endemism appears to be the main process in Kashmir Himalaya which points towards their progressiveness (Figure 4). In view of almost total lack of palaeo endemics in high-altitude zone of Kashmir Himalaya, the area does not seem to have served as a repository for many ancient taxa, despite the occurrence of systematically isolated families and genera[17]. On the contrary, the area is known to represent relatively recently evolved genera (*Semipervivella* – west Himalaya, *Picrorhiza* – Himalaya, *Jaeschkia* – west/central Himalaya). However, the above results cannot be generalized for the whole region in view of the availability of inadequate data.

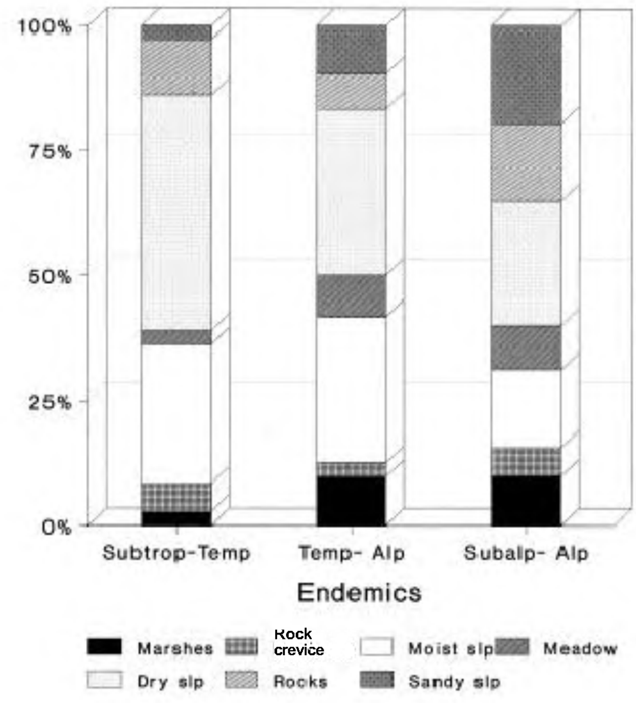

Figure 3. Distribution of habitats of endemic species ($n = 333$) at different altitude zones.

Conservation implications

High-altitude zone and PAs

Dominance of endemic elements at high-altitudes, especially in trans/north-west and west Himalaya suggests high conservation value of the zone. These facts need to be recognized while developing new protected areas (PAs) or extending the boundaries of existing ones. While using data on endemic diversity as one of the important attributes of ranking priority sites in timberline zone of west Himalaya, a study[21,22] revealed that some of the relatively small non-protected areas (Pindari: 76.7 km^2 area; 39.8% endemics) with high endemic diversity ranked highest on priority. This shows that even a relatively small area can serve as a rich re-

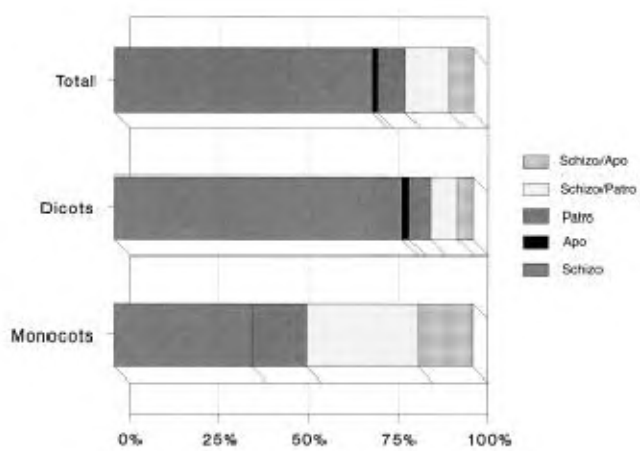

Figure 4. Representation of different types of endemics in Kashmir Himalaya ($n = 333$).

pository of endemic diversity. Although conservationists argue in favour of large reserves, the support for establishing smaller units is gaining ground in recent years[52–54]. Therefore, there is an urgent need to identify rich endemic areas, so that their inclusion in PAs is ensured.

Trans frontier parks

Since biogeographic units alone determine the patterns of distribution of endemics, it is pertinent to identify adjacent country borders rich in endemic diversity to initiate the process of establishing viable trans frontier parks. They are also reported to serve as peace parks[55]. The distribution of a large number of near endemics extends beyond the existing boundaries of Indian Himalaya. Therefore, it is important that concerned political entities collaborate to initiate conservation initiatives. In this context it is important to mention that over 21 trans frontier reserves already exist in different parts of the world[56]. Such initiatives have offered opportunities for international collaboration for effective conservation.

Economic value

Endemic taxa have figured prominently in grouping rarity classes[57]. Besides rare endemics, diversity of anthropogenic/economic endemics in the Himalaya reveals the occurrence of 62 (3.5%) narrow and 208 (11.9%) near endemics among medicinal plants[35] and 39 (5.8%) narrow and 93 (13.8%) near endemic wild edibles[33]. These attributes further contribute to the conservation value of endemics, especially in view of emerging global scenario on Intellectual Property Rights (IPR), patent laws and other related issues.

Genetic diversity

Reviews on correlation between species traits and allozyme diversity suggest that endemics generally possess low genetic diversity at species and population level[58]. This has been attributed to geographic isolation (no gene flow) and genetic drift (small population size). A comparison of levels of genetic polymorphism in geographically restricted and widespread species indicates that the former exhibits lower levels of genetic polymorphism than the widespread taxa. And, importantly, some restricted taxa possess only a small fraction of the genetic polymorphism observed in widespread congeners[59]. In the context of Himalayan endemics, two important issues emerge. One, genetic polymorphism in neo-endemics may depend on extent of variation in the ancestral population and two, the proportion of that variation carried over to the endemic taxon. Level of genetic polymorphism may also be related to the habitat diversity of the populations of restricted taxa. In view of the far-reaching implications of the role of genetic diversity in prioritizing conservation measures, such studies need to be initiated.

Thus, it is pertinent to advocate the importance of endemic taxa not only due to their unique distribution pattern, but more importantly, the manifestations they carry along, be it taxonomic, ecological, economic, evolutionary, cytological or genetic. In recent studies[39], their role has even figured as key-stone elements of biodiversity. An endemic taxon can possess multiple range of attributes, such as small population size, high economic value, specific habitat and low genetic diversity. All these features or any one of them calls for a thorough investigation on life strategies and biology. It is only after adequate understanding of the subject, that one can evolve a practically feasible strategy for conservation and sustainable use of endemic plants of the Himalaya.

Strategies for action

While recognizing the importance of endemism in biodiversity conservation, it is amply clear that the studies on this subject have not been undertaken systematically. It is a serious anomaly, which needs to be attended to. It is pathetic that even a comprehensive list of Himalayan endemic species is not available. We cannot afford to lose more time, especially in view of contemporary global thinking and possibilities of losing important and novel biomolecules in the process. Perhaps, inventorization of endemic species should assume first priority and once that is accomplished, an approach for prioritization of species and strategies can follow. The paper has attempted to develop an approach for prioritization on the basis of sensitivity of issues and species, providing rationale at each step.

Approach for prioritization

The approach considers the relative importance of biological and socio-economic features of endemic species.

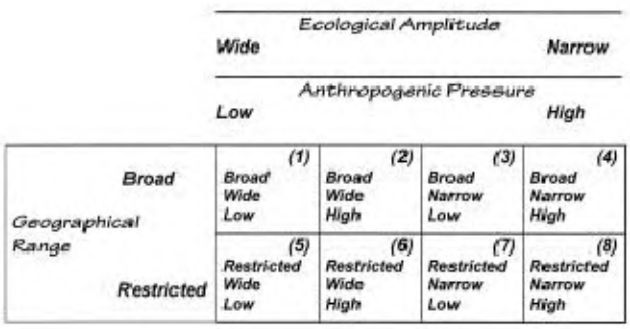

Figure 5. Eight-celled matrix for prioritization of endemics.

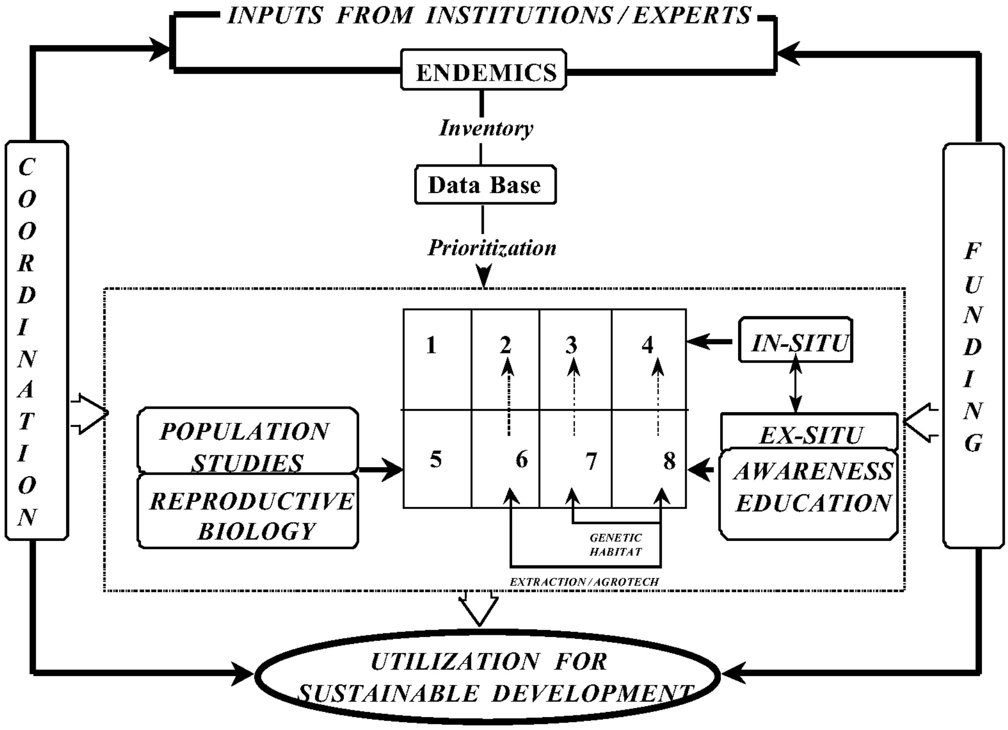

Figure 6. Flowchart showing the plan of action on prioritization for undertaking activities on priority species.

Three important attributes were considered, viz. geographic range, ecological amplitude and anthropogenic pressure.

On the basis of the above-mentioned features, an eight-celled matrix was developed (Figure 5). The first four cells (1–4) have broad, whereas the last four cells (5–8) have restricted geographical range. The taxa having broad geographical range cells (1–4) do not require immediate action on priority. On the other hand, the taxa having restricted geographical range cells (5–8) need immediate scientific investigation to understand their life-cycle strategies. As one moves from cells 5 to 8, the level and complexity of desired inputs increase (Figure 6). The nature of investigations required to be undertaken depends on the dominant sensitive attribute it possesses. For example, in cell 5, restricted geographical distribution, being the only qualifying attribute, calls for initiating studies on population demography and reproductive biology. Such studies need to continue with increasing intensity as we move toward cell 8. In cell 6, the restricted distribution is accompanied by high pressure, therefore, understanding trends of extraction and developing agrotechnology package is envisaged to be a priority. Through this approach, characteristic of each cell calls for a specific action. Apart from research inputs, management plans need to be developed covering activities in *in situ*, *ex situ*, awareness and education. This cannot be achieved without the participation of indigenous communities of high-altitude Himalaya, such as Gujjars, Gaddies, Bhotiyas, Monpas, etc. These communities have carved a niche in developing innovative methods of resource conservation and management. They are the ones who have contributed significantly in the development of ethnomedicine, utilization of wild edibles and conservation of traditional crop varieties. What is therefore needed is a balanced blend of *ex situ* technologies and other scientific inputs from academics and conservationists on the one hand and *in situ* initiatives from participating communities, NGOs, traditional institutions and government organizations, on the other. This is expected to ensure the maintenance of repositories of endemic biodiversity.

The above plan of action needs a very efficient and dedicated coordinated effort by a number of institutions and groups who have contributed in biodiversity conservation of the Himalaya. Achievement of any one objective will largely depend on the human and monitory resource mobilization of National Science and Technology funding agencies.

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