the anatomical parameters of F_1 were better with medium range of value and suitable for selection. The F_1 had male inflorescence like male parent but bigger in size. The pollen viability of male parent was 75–80% whereas in F_1, the pollen viability ranged from 90 to 95%. In higher ploidy, pollen viability is generally low, but F_1 hybrid showed higher pollen viability with better pollen germination (80%). In case of growth traits all the parameters showed higher value in F_1 hybrid compared to the female parent. The F_1 hybrid showed heterosis over both parents in respect of leaf moisture percentage, leaf moisture retention percentage, leaf yield/plant and rooting percentage. The parent *M. serrata* is poor in rooting percentage and showed less than 5% rooting (Figure 2 *a*–*c*).

But the hybrid plant exhibited more than 95% rooting. The female parent is good in quality parameters, but not widely accepted due to its low yield and moderate rooting (65%). Performance of the F_1 hybrid is comparatively better than both parents. *M. serrata* is not generally used for sericulture due to its rough, thick and tomentose leaf. The F_1 hybrid showed smooth leaf, like the female parent with more leaf area and was thus suitable for silkworm rearing.

Thus the pre-breeding effort highlights the possibility of using wild *M. laevigata* and *M. serrata* effectively and efficiently. A similar result was also reported in cotton[17]. Stewart and Mc[18] indicated the possibility of obtaining recombinants through backcross for various traits. It is also possible to obtain recombinants through backcross in mulberry. Efforts in this regard are under progress to obtain abundant population and isolate the desired plant through careful observations. The perennial crops require more gestation period for establishment and expression of characters, which is also to be noted. The F_1 plants also showed the characters of high biomass, vigorous growth, profuse fruit formation, and timber yield that can be exploited for non-sericulture use.

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Current status, distribution and conservation of rare and endangered medicinal plants of Kedarnath Wildlife Sanctuary, Central Himalayas, India

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Assessment of population structure on the basis of density, distribution and diversity-dominance pattern was carried out in Kedarnath Wildlife Sanctuary, Uttarakhand, India. Besides, distribution pattern, population structure and conservation status of ten rare and endangered medicinal plants were also evaluated. Different habitat types for these species were identified and sampled using vertical belt transects. Out of ten habitats identified, distribution of most of the species was found to be restricted in 2–3 habitats. However, *Picrorhiza kurrooa* showed wide distribution in six habitats, while *Swertia chirayita* was restricted to a single habitat. On the basis of density, occurrence in different habitats and level of pressure, we have

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grouped them into two broad categories: (i) restricted distribution and high pressure, and (ii) well distributed and low pressure. Accordingly, implication of conservation and management strategies has been suggested.

Keywords: Conservation, density, diversity, habitat types.

BIODIVERSITY in wild and domesticated plants forms the source of food, medicine, oil, fibre, fuel, housing, clothing and other materials, including culture of mankind. Conservation of national resources and maintenance of essential ecological processes of life-support systems has, therefore, become the crucial need of the day. Conservation biologists warn that 25% of all species could become extinct during the next 20 to 30 years[1]. Causes for the loss of species are numerous, but the most important is the loss and fragmentation of natural habitats. In the Himalayan region, a chronic form of disturbance is found in which people remove only a small fraction of forest biomass in the form of grazing, lopping, surface burning and litter removal. The problem with this form of disturbance is that plants or ecosystems often do not get time to recover adequately because the human onslaught never stops[1–3].

India is home to a great variety of ethno-medicinally important plant species, and is ranked sixth among 12 mega diversity countries of the world. The Himalayas is designated as one of the global biodiversity hotspots, where ecological, phyto-geographical and evolutionary factors favour high species diversity. It supports about 18,440 species of plants, of which 25.3% is endemic to the region[3,4]. The rich plant diversity of the Indian Himalaya is utilized by the native communities in various forms, including food and medicine. During the past several years, some important contributions have been made on ethnobotanical knowledge and medicinal plants of Central Himalayas[4–11].

The Convention on Biological Diversity (CBD) recognized and reaffirmed the fundamental requirement of *in situ* conservation of ecosystems and natural habitats[1] in its Article 8. Protected areas are one of the most widely accepted and practically approachable to biodiversity conservation the world over. In addition to conservation objectives, the protected areas also have significant scientific, educational, cultural, recreational and spiritual value apart from the direct and indirect benefits they provide to local as well as national economy. These methods not only seek to protect representative arrays of ecosystem and their constituent biodiversity in different biogeographic regions by regulating human and other biotic activities, but also ensure natural growth, proliferation and perpetuation of species as part of their natural ecosystems. One of the prime objectives of this protected area is to assess and monitor diversity and dominance pattern at regular intervals, so that conservation status could be evaluated. The present observations are in relation with these objectives. Kedarnath Wildlife Sanctuary (KWLS), Uttarakhand, India was selected for assessment of status and conservation of threatened and medicinally important plants vis-à-vis information on plant utilization by local people of the sanctuary. This communication also focuses on valuable information regarding botanical richness, distribution and availability of medicinally important plants of the area.

The study was conducted during 2003–05 under the Biodiversity project scheme of the Department of Science and Technology, Govt of India. The study area, KWLS covers most part of Okhimath Block, Rudraprayag District, Uttarakhand, Central Himalayas (Figure 1). The sanctuary was established in 1972 with total area of 975.20 sq. km and is also famous for the Musk Deer Sanctuary, situated in the northeastern part of Garhwal Himalayas. The area comprises a broad range of altitudinal gradients from nearly 800 m in the lower part which experiences submontane climate to almost 6000 m asl forming the Great Himalayan range, including alpine regions. Owing to the wide altitudinal gradient, this area has unique physiognomic, climatic and topographic conditions. The area receives 300 cm of annual precipitation of which the rainy months (June–August) contribute approximately 60%. The relative humidity varies from 35 to 85% annually. There is moderate to heavy snowfall during December–February, even in low-altitude areas. The mean maximum temperature varied between 2.5 and 35°C (June). Besides the grandeur of Himalayan wilderness, the area encloses many important shrines, including Madhyamaheshwar (3200 m), Rudranath (3500 m), Trijuginarayan (2200 m) and Tungnath (3750 m), while Kedarnath (3400 m) is almost on its northern boundary.

The vegetation of different parts of the study area was thoroughly explored by repeated visits during different seasons of the year, covering all ecological habitats represented in the area. Plant specimens were collected and preserved following methods suggested by Gaur[7]. The specimens were identified following Gaur[7] and Naithani[8].

During the visits, different habitats of the study area were identified. For the status survey, populations of selected species in various habitats were identified using vertical belt transacts, 60 m long and 30 m wide[12]. Ten quadrats of 1 × 1 m size were laid randomly in each stand. Individuals of all species were counted in each quadrat. For rhizomatous species, each sprouting or flowering shoot was counted as one individual. Analytical features for the population study such as percentage frequency (%*F*), density (*D*, plant per sq. m) and total basal cover (TBC, sq. cm/sq. m) was calculated following Misra[12]. Diversity indices (Shannon–Wiener index[13]) for species diversity measurement, i.e. $H = \sum[(ni/N)\log(ni/N)]$ and index of dominance (Simpson index[14]) for measurement of dominance, i.e. $Cd = \sum(ni/N)^2$ were also computed as ecological measures to study natural ecosystems for assessment of diversity and relative dominance. On the

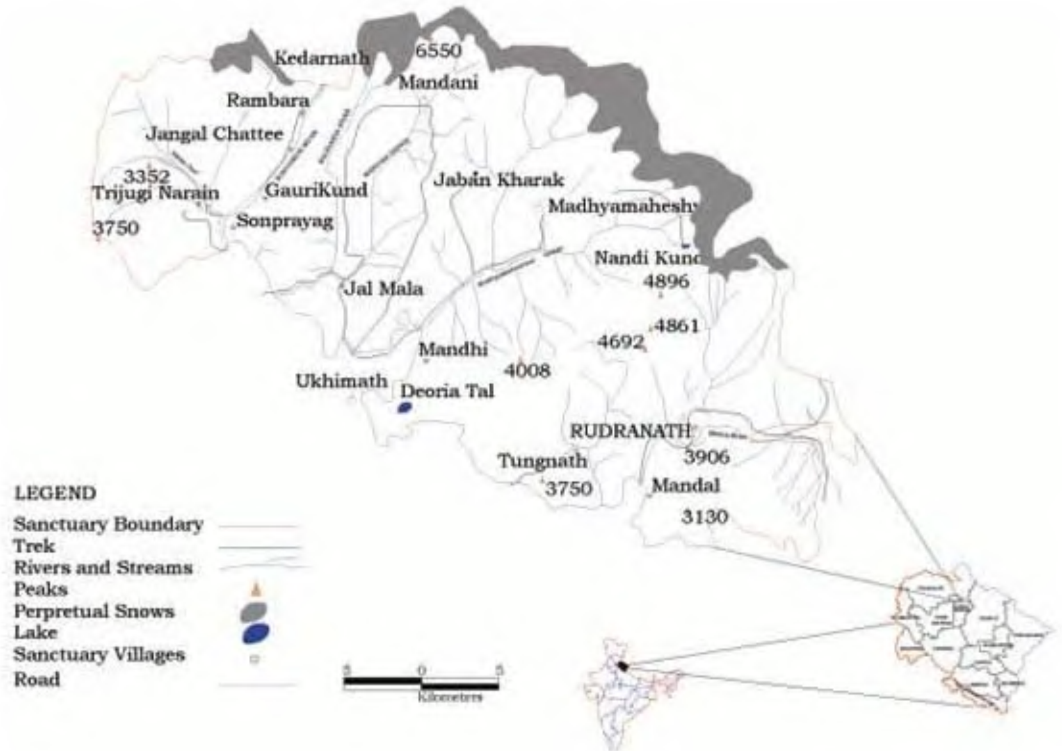

Figure 1. Complete map and important ground control points of the KWLS.

basis of plant density (population estimation), status of the species was determined for the entire area according to IUCN Red List Categories[15,16].

An ethnobotanical survey was conducted on the basis of interviews with local people, vaidyas, herbal practitioners, older members of the community, Palsi (shepherds), etc. For this, a questionnaire was prepared and information related to local name, local uses and plant parts used for various purposes (ethnobotanical importance) for each species was collected. Plant species used in local systems were collected with the help of these people, identified, and herbarium specimens were deposited in the collection of the Department of Environmental Biology, University of Delhi.

A survey was conducted for two years during 2003–05 in KWLS, and based on altitudinal gradient and physiognomy, different forest types and microhabitats were identified. Four major forest types with ten major habitats were identified in detail (Table 1). Table 1 reveals that the area has diverse topography with wide altitudinal gradients and thus possesses a large number of plant species. Forests of the KWLS are pine-dominated at lower altitude (800–1800 m) followed by mixed deciduous at middle altitude (1500–2500 m) and mixed-evergreen/coniferous forest near tree line. However, based on topographic conditions, different habitats were also observed. During the floristic survey, nearly 400 species of 230 genera and 89 families were collected from the area.

Based on extensive survey and availability of medicinal plants in the KWLS, ten high value, rare and endangered medicinal plants (REMP), equally important for conservation, were selected for observations on population status, dominance and diversity in the area. These species were present only in high-altitude areas between 2400 and 4000 m and were present within ten habitats (Table 2). Vernacular names, altitudinal ranges of habitat, parts used and status as assigned in *Red Data Books*[15–17] and CAMP report[17] are also depicted in Table 2. It appears that all these species are vulnerable and critically endangered in status, indicating extensive and illegal exploitation from the wild, although the area is under protection and banned from commercial exploitation.

It was found that populations of selected REMP species varied in different habitats (Table 3). *Picrorhiza kurrooa* was found in six different habitats and *Nardostachys jatamansi* in four, while *Aconitum balfourii*, *Berberis osmastonii*, *Dactylorrhiza hatagirea* and *Podophyllum hexandrum* were present in three different habitats. In the KWLS, *Swertia chirayita* was found in the forest floor having only one habitat of a comparatively small area. *A. balfourii*, *A. heterophyllum*, *D. hatagirea*, *P. kurrooa* and *S. chirayita* had lower average density (2.3–4.9 individual/sq. m) in different habitats. Likewise, *Allium stracheyi*, *B. stracheyi*, *B. osmastonii* and *N. jatamansi* had the highest density (10.6–13.2 individual/sq. m) in the respective habitat. Observations revealed that though some

Table 1. Forest and habitat types in Kedarnath Wildlife Sanctuary, Central Himalayas, India

Forest type and altitude (m asl)	Major habitats	Remarks
Sub-montane forest (800–1500)	Sparse pine	Steep dry slopes, pine-dominated
	Mixed deciduous	Sparse forest area, mixed type of forest
Montane forest (1500–2800)	Under shrub	Degraded forest land dominated by shrubs
	Moist rocks	Southwest facing rock outcrops and rocky crevices, sparse tree vegetations
	Dry rocks	Dry landslide area and rocky steep slopes
Sub-alpine (2800–3500)	Dispersed timberline (2800–3200 m)	Scattered trees of *Quercus semicarpifolia* with open sub-alpine slopes dominated by herbs and grasses
	Krumholtz zone 2800–3400 m	Dominated by scrubs of *Rhododendron campanulatum*, *Q. semicarpifolia*, etc. mostly on moist slopes
Alpine region (3000–4500)	Under scrub 3000–3500 m	Dominated by scrubby vegetation, mainly *R. hypenanthum*, *R. campanulatum*, *Juniperus* sp.
	Meadows	Moderate slopes dominated by herbs
	Pastureland (grassland)	Steep grassy slopes

Table 2. REMP species selected for population estimates in the KWLS

Species	Local name	Altitude (m)	Habitat	Part used	Status		
					RDB	CAMP	NMPB
Aconitum balfourii Stapf.	Meetha	3000–4000	SS, AM, USC	Tuber	Vu	Vu	√
Aconitum heterophyllum Wall. Ex Royle	Atees	3000–4000	AM, UM	Tuber	Vu	Cr	√
Allium stracheyi Baker	Pharan	2500–3000	MR, DR, SSL	Leaf, Bulb	Vu		
Bergenia stracheyi (Hook) Th.	Silphori	2700–3400	MR, SS	Rhizome	Vu		
Berberis osmastonii Dunn	Kingore	2400–3200	F, US, USC, SSL	Root	En		√
Dactylorrhiza hatagirea (D. Don.) Soo.	Hathajari	2600–3400	AM, USC, UM	Root	En	Cr	√
Nardostachys jatamansi (D. Don.) DC.	Jata massi	3000–5000	MR, DR, SS, USC	Rhizome	Vu	Cr	√
Picrorhiza kurrooa Royle ex	Kutki	3000–4500	F, UM, MR, SS, AM, USC	Stolen	Vu		√
Podophyllum hexandrum Royle.	Bankakri	2500–3600	DR, SS, USC	Root	En	En	
Swertia chirayita (Roxb.) ex Fleming	Chiryata	2700–3500	F/US	Root	Vu	En	√

F, Forests; US, Under shrub; RS, Rocky slopes; MR, Moist rock; DR, Dry rock; SS, Scree slope; AM, Alpine meadows; USC, Under scrub; SSL, Steep slope; UM, Undulating meadow; RDB, *Red Data Book*; Vu, Vulnerable; Cr, Critically endangered; En, Endangered; NMPB, National Medicinal Plants Board Priority List; CAMP, Conservation Assessment and Management Plan – Shimla, Report for Uttarakhand regarding population status in Garhwal Himalaya.

species may be present in a variety of habitats, their populations would be high in particular habitats. In addition, it was also observed that even in their favoured habitat almost every species had patchy distribution and was restricted to a small area. A comparative account of the present study with others[18–24] pertaining to the alpine area of the Western Himalayas further reveals that density of selected species was far below that of many species of the alpine region (Table 4).

Species richness, diversity and dominance pattern varied markedly in different habitat types. It was found that AM had maximum species richness among different habitats followed by MR, SS and F (Figure 2). During the present study, diversity index (H) was used for an expression of species abundance and diversity-dominance relations. This index gives greater weight to rare species and represents a type of formulation widely used in assessing complexity and for comparing diversity components[1,2]. Species diversity also showed the same trend as species richness. It was maximum in AM followed by SSL, SS and F and minimum in US habitats. On the basis of diversity (H) values, AM was the best habitat for maximum diversity, while US and DR had low species diversity in the KWLS (Figure 2).

It was observed that the habitat (US) with lowest species diversity had maximum concentration of dominance and the habitat with maximum species diversity (AM) had the lowest value for concentration of dominance. Concentration of dominance, which always ranges from 0 to 1, indicates species dominance within community and gives greater weight to common species. In addition, values of Cd closer to 1 indicate areas dominated by single or few species (Figure 2).

Table 4 summarizes population status of selected species in different parts of the Himalayas. A comparative account of the present study regarding status of selected species with other studies[21–27] reveals that most of the species had higher density compared to other areas as well as protected

Table 3. Population density (individuals/sq. m) of REMP species in different habitats of KWLS

Species	F	US	MR	DR	SS	AM	USC	SSL	UM
A. balfourii					5.1	3.2	6.5		
A. heterophyllum						3.1			4.2
A. stracheyi			3.2	18.1				4.3	
B. stracheyi			16.2		10.2				
B. osmastonii	11.1	12.1					14.5	10.1	
D. hatagirea						2.3	4.4		3.8
N. jatamansi			15.6	2.3	1.4		1.2		
P. kurrooa	2.5		2.5		5.2	1.2	5.6		4.4
P. hexandrum				3.2	1.2		10.2		
S. chirayita	2.3								

Table 4. Population status (individuals/sq. m) of REMP: A comparative account

	NW Himalaya			Protected areas of NW Himalaya		
Species	KH[a]	GH[b]	ITH[c]	NDBR[d]	VOF[e]	KWLS[P]*
A. balfourii		1.9				4.9
A. heterophyllum		1.4				3.6
A. stracheyi	0.5	–	–	9.00	–	10.6
B. stracheyi	1.2		9.9	–	0.8	13.2
B. osmastonii						12.4
D. hatagirea	0.5		16.3	4.2	1.0	3.5
N. jatamansi		23.3				2.6
P. kurrooa	3.9		0.71	–	4.5	2.2
P. hexandrum	0.2		2.5	–	–	4.8
S. chirayita						2.3

[a]Uniyal *et al.*[24]; [b]Nautiyal *et al.*[19,26]; [c]Kala[21–23]; [d]Maikhuri *et al.*[20]; [e]Kala *et al.*[22].
[P]Present study, *Relative density of each species.

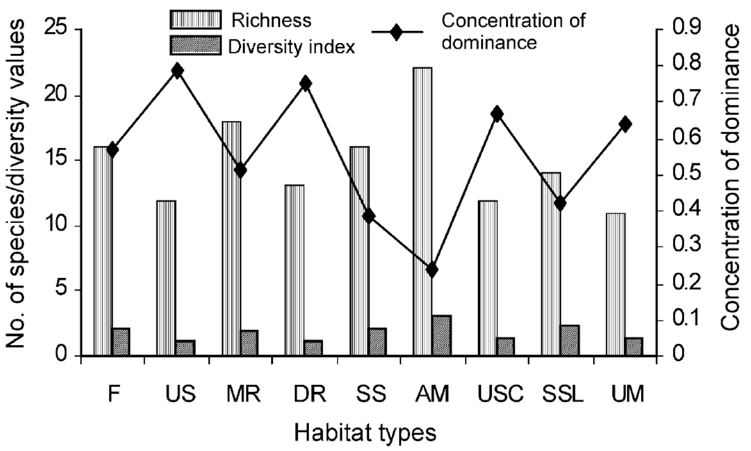

Figure 2. Species richness, diversity and concentration of dominance along different habitats in the KWLS.

sites of the region. The study indicates positive response by species populations of the site being a protected area (sanctuary). However, as mentioned under population estimation, all species had comparatively low density than other high-altitude species with habitat specific occurrence. Therefore, species are still on the verge of threat status and need long-term conservational efforts. Low density of *A. heterophyllum*, *D. hatagirea* and *S. chirayita* in the present study site may be due to restricted distribution and high pressure, legal and illegal exploitation by local inhabitants for use in the local health system, and also high demand in the market.

High altitude medicinal plants of the Himalayas were always targetted by local medical practitioners, vaidyas and plant explorers since time immemorial[4]. Decreasing population of REMP in the wild due to illegal exploitation of these species, has raised discussions among conservationists, ecologists and scientists[1,20,23,25]. It is observed that among many factors involved in the decreasing number of species from the wild, the most important is the restricted distribution of plant species and anthropogenic pressure in the form of over harvesting, overgrazing, trampling and extraction. It is observed that *A. balfourii*, *A. heterophyllum*, *D. hatagirea*, *P. kurrooa* and *S. chirayita* had localized distribution in their habitat, while *A. stracheyi*, *B. stracheyi*, *B. osmastonii* and *N. jatamansi* were widely distributed in their respective habitats. On the basis of population status, distribution pattern and level of anthropogenic pressures in the present study area, the studied/surveyed REMP species were grouped into two broad categories. Species comprising high trade value in the market included *A. heterophyllum*, *D. hatagirea*, *P. hexandrum*, *P. kurrooa*, *S. chirayita* and *N. jatamansi*. These were grouped in restricted distribution and high pressure (RDHP) category, while *A. balfourii*, *A. stracheyi*, *B. stracheyi* and *B. osmastonii* fall in the category of well distributed and low pressure (WDLP), probably due to low demand in the market.

Considering the above facts, besides protecting these plants under the protection area networking (sanctuaries, parks, biosphere reserves) for conservation and management policies, a criterion should simultaneously be evolved to judicially put to use the needy medicinal plants for the benefit of mankind. At the same time, habitat specificity should also be kept in mind for large-scale production of medicinal plants.

Ten REMP species had high demand and greater potential in the curing of different ailments by medical practitioners, local people and vaidyas. It is suggested that few families from each villages, inside and near the KWLS area should be encouraged to begin large-scale cultivation of these RDHP medicinal plant species, so that it will reduce illegal extraction activity in the area.

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