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Plant Species Diversity along an Altitudinal Gradient of Bhabha Valley in Western Himalaya

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Abstract: The present study highlights the rich species diversity of higher plants in the Bhabha Valley of western Himalaya in India. The analysis of species diversity revealed that a total of 313 species of higher plants inhabit the valley with a characteristic of moist alpine shrub vegetation. The herbaceous life forms dominate and increase with increasing altitude. The major representations are from the families Asteraceae, Rosaceae, Lamiaceae and Poaceae, suggesting thereby the alpine meadow nature of the study area. The effect of altitude on species diversity displays a hump-shaped curve which may be attributed to increase in habitat diversity at the median ranges and relatively less habitat diversity at higher altitudes. The anthropogenic pressure at lower altitudes results in low plant diversity towards the bottom of the valley with most of the species being exotic in nature. Though the plant diversity is less at higher altitudinal ranges, the uniqueness is relatively high with high species replacement rates. More than 90 % of variability in the species diversity could be explained using appropriate quantitative and statistical analysis along the altitudinal gradient. The valley harbours 18 threatened and 41 endemic species, most of which occur at higher altitudinal gradients due to habitat specificity.

Keywords: Plant species diversity; threatened species; altitudinal gradient; flora; Bhabha Valley; western Himalaya; India

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Introduction

The increasing potential threat to biological diversity is an irreversible environmental disorder that warrants immediate remedial measures for sustainable management and conservation of biodiversity. Himalaya is one of the mega biodiversity regions of the world (Heywood 2000). The western Himalaya, though not as biologically rich as the eastern Himalaya, offers unique habitats to sustain several endemic and rare plant taxa. Distinctive features of the Himalayan region are its valleys, which support a rich biodiversity, and rivers and streams which offer a perennial source of water. The vegetation comprising evergreen forests with pure stands of *Pinus roxburghii*, *Quercus* spp., *Pinus wallichiana*, dry temperate and alpine forests representing varied species compositions, make the valleys rich in plant diversity. Moreover, the valleys and the hills provide altitudinal gradient, which can harbour rich plant diversity.

The variations in species diversity can be linked to several ecological gradients (Grime 1979, Palmer 1992, Huston and DeAngelis 1994). Altitudinal gradient is well known to be one of the decisive factors shaping the spatial patterns of species diversity (Szaro 1989, DeBano and Schmidt 1990, Lieberman et al. 1996, Zimmerman et al. 1999, Brown 2001, Lomolino 2001). Although a clear and accurate description of the pattern of elevation gradients in diversity was put forward nearly two centuries ago, the issue still remains uncertain (Lomolino 2001). Several studies reported that diversity peaks at intermediate elevations, *e.g.*, in tropical rain forests (Lieberman et al. 1996, Vazquez and Givnish 1998, Zimmerman et al. 1999). In general, in Himalaya humped (unimodal) curve of species diversity was observed with increasing altitude (Vetaas and Grytnes 2002). However, Garkoti and Singh (1995) reported that the decrease in species diversity corresponded to decline in net primary productivity and biomass of forests along an altitudinal gradient. The species diversity in *Pinus roxburghii* communities showed hump-shaped curve in sourthern slopes in comparison with continous decline in northern slopes (Rawat and Pant 1999). Tree layer diversity was found to be higher in the middle part of the gradient (Saxena et al. 1985) in the western Himalaya. However the decrease in shrub layer diversity was observed with increasing attitude (Bhandari et al. 1997). Even in cold desert region of Ladakh, where there is no arboreal forest, along the altitudinal gradient hump-shaped relationship was observed (Klimes 2003). There are however a number of notable exceptions to the reported hump-shaped pattern (Stevens 1992, Pausas and Austin 2001, Rey Benayas and Scheiner 2002). Lomolino (2001) argued whether the diversity-elevation gradient is increasing or decreasing, or modal with a peak at intermediate elevations, will depend largely on patterns of co-variation and interaction among the geographically explicit variables.

The Bhabha Valley, situated in the east of River Sutlej, is floristically as well as ecologically unexplored landscape of western Himalaya which represents a rich floral and habitat diversity. The floristic surveys of this Himalayan zone other than those by Hooker (1872 ~ 1897) were largely restricted to narrow political boundaries (Collet 1902, Rau 1975, Chowdhery and Wadhwa 1984, Chauhan 1999, Aswal and Mehrotra 1994, Gaur 1999). Due to its transitional geographical position between moist temperate area of Kinnaur and cold deserts of Lahaul-Spiti districts of Himachal Pradesh, it is a unique landscape in terms of species diversity. It provides a large elevation gradient and covers a lot of heterogeneity of habitats, which governs the species distribution.

Hence, the present study highlights the floristic diversity of the Bhabha Valley and its correlation with altitude.

1 Study Area

The Bhabha Valley (from 31.54 N and 77.95 E to 31.78 N and 78.05 E; between 1,500 m and 5,600 m above msl) lies at the basin of Bhabha, also known as River Wangar, a small tributary of River Sutlej in district Kinnaur of Himachal Pradesh, India (Figure 1). The valley is lined with the Srikhand Mahadev Range where small peaks and glaciers descend to miles of high-altitude pastures dotted with alpine flowers. It is located adjacent to the Pin Valley of Lahaul-Spiti and is connected by the Pin-Bhabha Pass (4,605 m amsl). By virtue of its geographical location and elevation, it enjoys a temperate climate with long winter stretching from October to May and short summer from June to September. Summer is warmer, with temperature sometimes rising to more than 25°C. The precipitation is in the form of both snow and rainfall. The mean annual rainfall as recorded at an adjacent weather station (Kalpa, Kinnaur) is 917 mm.

2 Material and Methods

2.1 Field survey

Floristic surveys were undertaken from April, 2002 to September, 2004 to assess and document the species diversity of the flowering plants of the valley which starts from the confluence of the Bhabha and Sutlej rivers at an altitude of around 1500 m and reaches an altitude of 4605 m leading to the Pin Valley through the Pin-Bhabha Pass. A Shuttle Radar Technology Mission (SRTM) Digital Elevation Model (DEM) with a resolution of 90 m (USGS) was used to segregate the study area into six classes of altitudinal range with 500 m increment (i.e., from 1,501 to 4,500 m msl) (Figure 1). Above 4,500 m altitude the area is covered with perennial snow. The interval of 500 m for each altitudinal class was fixed keeping in mind the steep and tough terrain of the study area, a better comprehension using DEM and to obtain statistically significant comparable datasets of plant species along the gradient. In each altitudinal interval, enumeration of higher plant species was done to determine the species richness. The voucher specimens of the plants were collected and processed according to standard herbarium procedure (Jain and Rao 1976). The plant species were identified by consulting different floras of the western Himalayan region (Rau 1975, Nair 1977, Aswal and Mehrotra 1994, Gaur 1999) and were confirmed with authentic specimens lodged in the herbarium of Botanical Survey of India (BSI), Dehradun, India. All authenticated specimens were deposited in the herbarium of the Institute of Himalayan Bioresource Technology, Palampur (H.P.), India. The checklist of higher plants is presented in Table 1 (at the end of the text) which is a first ever report on the flora of the valley. Status of threatened plants was ascertained from the available literature (Kala 2000, Nayar 1996), Red Data Book of Indian Plants (Nayar and Sastry 1987 ~ 1990) and CAMP Report (Ved and Tandon 1998).

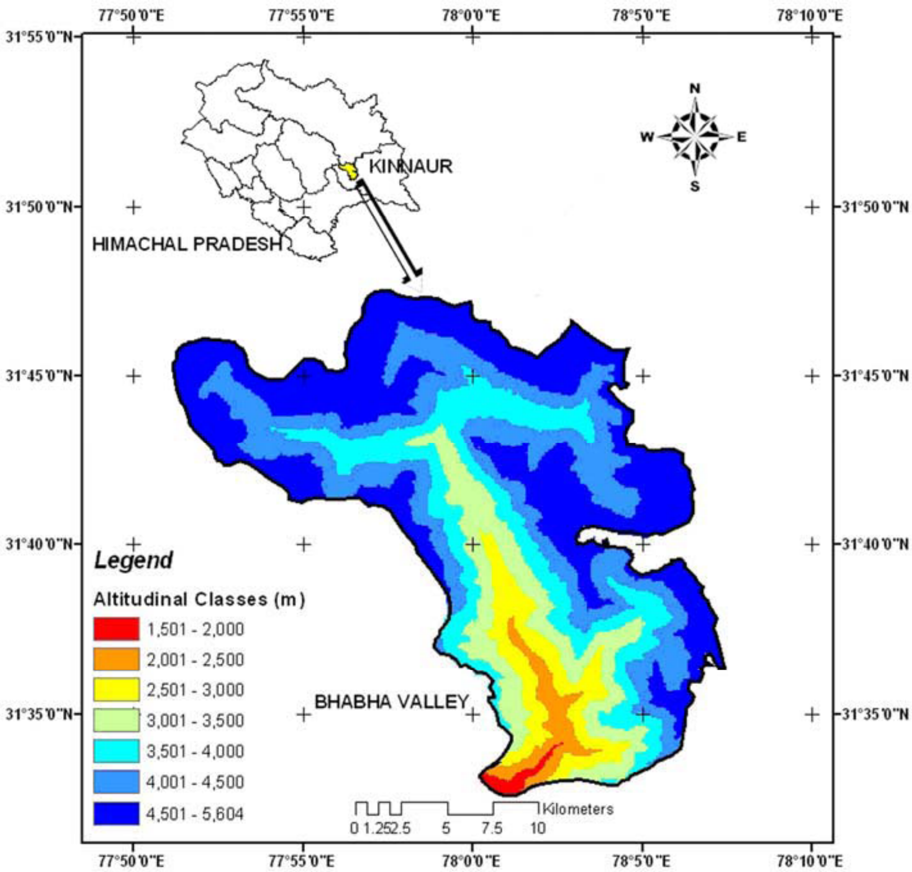

Figure 1 Location map of Bhabha valley classified into 500 m altitudinal classes using a Digital Elevation Model (DEM)

2.2 Data analysis

The species diversity is determined in terms of number of species and mentioned as species richness (McIntosh 1967). Data extraction and analysis were done in MS-Excel using established techniques. The relationship between species richness with elevation gradient and distributional range of species was analyzed statistically using non-linear regression. A 'Rank Correlation Coefficient' was determined between families and their species richness by assigning ranks in order of dominance. It was observed from the study that a number of species were stenotopic / stenoecious and restricted to a specific altitudinal range of 500 m only (termed herein as unique species). Species uniqueness was determined by recording the species restricted to the specific altitudinal interval.

The maximum number of species in the valley was estimated from species accumulation curve which is a plot between cumulative numbers of species and sampling area (Henderson 2003). The curve follows Michelis-Menten equation and transcribes a hyperbola described by the following equation:

$$S(n) = S_{max}\, n / (B+n)$$

where, $S(n)$ = Number of species up to the cumulative area (n), S_{max} = maximum number of species in the community and B = constant. The equation may also be written in the form:

$$1/S(n) = [(B/S_{max}) / (1/ n)] + (1/S_{max})$$

The y-intercept of the regression of the double reciprocal plot between $1/S(n)$ and $1/n$ provides the value of $1/S_{max}$.

Beta diversity was calculated based on species replacement rate with an increasing altitude (Wilson and Schmida 1984).

$$\beta_T = [g(H) + l(H)] / 2\alpha$$

where, $g(H)$ = number of species gained, $l(H)$ = number of species lost moving along the altitudinal gradient, α = average richness of species at the two intervals.

The surface (3D) and two dimensional (2D) areas were calculated for each class using ArcGIS 8.3 software.

3 Results and Discussion

3.1 Floristic composition

A total of 313 higher plant species belonging to 204 genera and 68 families were recorded from the Bhabha Valley (Table 1, at the end of the text). Among them, eight species belonged to gymnosperms (*Abies pindrow, Cedrus deodara, Picea smithiana, Pinus roxburghii, Pinus wallichiana, Taxus baccata, Juniperus communis* and *Juniperus indica*). Among angiosperms, dicots and monocots were represented by 268 and 37 species, respectively. Asteraceae was the largest family represented by 44 species followed by Rosaceae (19), Poaceae (18), Lamiaceae (17), Ranunculaceae (14) and Polygonaceae (14). Of the 68 families, 55 were found with five species or less each, and only four families with more than 15 species. Out of the total species, 56.41 % (*i.e.*, 176 species and 114 genera) belonged to ten dominant families.

Among the genera, *Polygonum* (8), *Geranium* (7), *Artemisia* (6), *Potentilla* (5), *Anaphalis* (5), *Nepeta* (5) and *Saussurea* (5) were found with more than five species. Asteraceae, dominating the Bhabha Valley, is also the most dominant family in Lahaul-Spiti, Bashahr Himalaya, Himachal Pradesh and in the high altitude regions of western Himalaya (Rau 1975, Nair 1977, Chowdhery and Wadhwa 1984, Aswal and Mehrotra 1994). The flora of the Bhabha Valley shows more affinity with the flora of the Lahaul-Spiti Valley. This is evident by the presence of dominant families being common to both the valleys. However, floristic composition of this valley differs from that of other parts of western Himalayan in terms of meager representation of the families Orchidaceae and Cyperaceae due to lower tree lines and fewer marshy lands. Family Orchidaceae, one of the prominent families in the western Himalayan flora, is represented in the Bhabha Valley with only two lithophytic species *viz. Dactylorhiza hatagirea* and *Herminium lanceum*. This may be due to the fact that a majority of orchids in western Himalaya are epiphytic whereas the lack of tree life-form in the Bhabha Valley does not support orchids. Another dominant family of western Himalaya is Cyperaceae, which is represented by a few species in the Bhabha Valley. The members of this family are considered to be widely distributed in varied topography and habitats. But they are limited in this valley probably due to lack of shallow lakes or ponds. Moreover, the major part of the valley is covered with snow throughout the year.

The presence of a large number of herbaceous families, such as Brassicaceae, Rosaceae, Scrophulariaceae, Ranunculaceae, Apiaceae and Polygonaceae, may be attributed to their alpine nature. The association between number of families (Y) and number of species per family (X) shows a log-log relationship (r = -0.9217, $p \leq 0.05$, n=5, Ln Y = -1.428 Ln X + 4.97)). This relationship reveals that the maximum diversity is attributable to a few families. The first ten dominant families account for 56.41 % of species diversity. Further, families with smaller number of species per family abound the valley. Families success as determined in terms of number of species per family follows a power function with high 'Rank Correlation Coefficient' (r = -0.9794, p ≤ 0.001, n=68) (Figure 2).

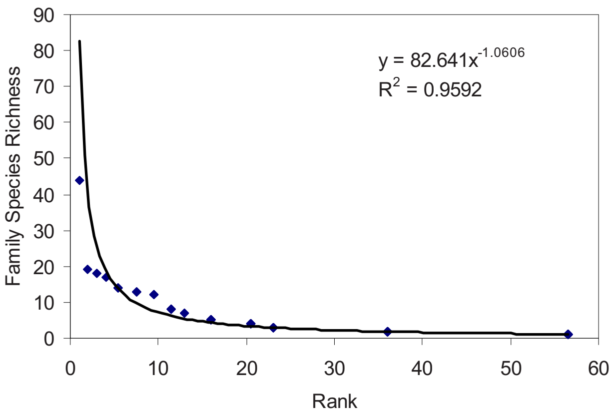

Figure 2 Rank family and species richness correlation

3.2 Relationship between altitudinal gradient and area

The surface area (3D) of each altitudinal class was determined and the difference computed with respect to planimetric (2D) area. The larger the difference, the more inclined is the surface. The differences in the areas at the lowest (1,501 ~ 2,000 m) and the highest (3,501 ~ 4,000 m) altitudinal ranges were 31.12 % and 21.28 %, respectively. Though the surface area was minimal at lower altitudinal gradients, the heterogeneity of habitats found at these gradients supported diverse vegetation types and harbour rich plant diversity. The largest area in the valley is at 4,001 ~ 4,500 m altitudinal class, but the lack of habitat heterogeneity and congenial environmental conditions at this altitude favours only a few plant species.

A plot of cumulative species and cumulative area follows a typical species area curve with high correlation coefficient for both the 2D (r=0.9928, p ≤ 0.001, n= 6) and 3D (r=0.9927, p ≤ 0.001, n=6) areas (Figure 3).

In order to find out the total species pool of the area, a double reciprocal plot was regressed between cumulative numbers of species and cumulative area. It shows a highly significant correlation (r = 1.00, p ≤ 0.001, n=6). The reciprocal of y-intercept reveals that the region could be harbouring about 500 species (Figure 4). The equation for the species-area accumulation curve comes out to be:

$$S_n = 500\, n / (37.5 + n),$$

where, S_n is cumulative number of species and n is the cumulative area (sq km).

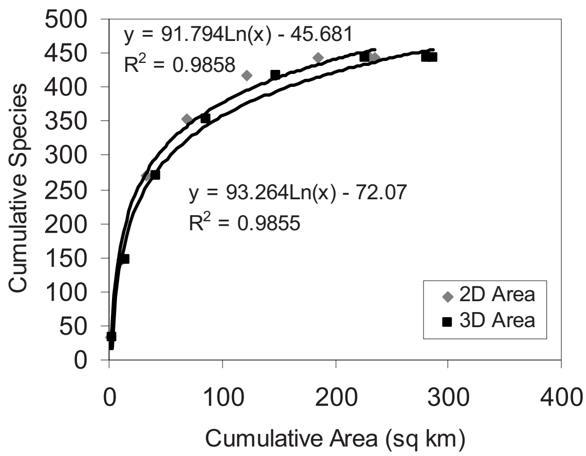

Figure 3 Species area accumulation curve

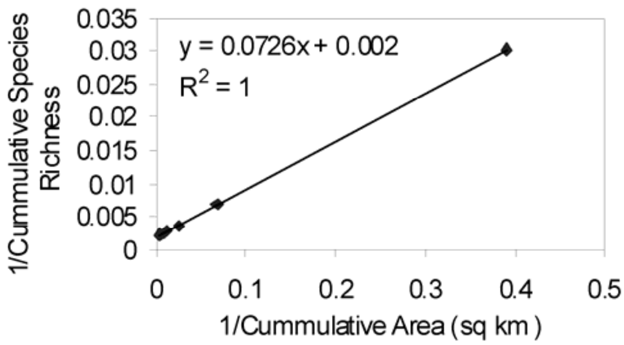

Figure 4 The double reciprocal plot for cumulative area (2D)

3.3 Relationship between altitudinal gradient and species richness

The number of species plotted against the altitudinal gradient showed a hump-shaped curve. The mid altitudinal ranges represented higher species richness which declined towards both ends of the altitudinal gradient. Maximum number of species were found in the range between 2,501 ~ 3,000 m (123 species belonging to 98 genera and 48 families) and followed by that between 2,001 ~ 2,500 m (113 species belonging to 90 genera and 39 families). The least number of species (26 species belonging to 21 genera and 14 families) were found in the highest range (4,001 ~4,500 m). A slightly higher number were found in the lowest range (1,501 ~ 2,000 m) (33 species belonging to 30 genera and 19 families). This suggests a unimodal relationship between species richness and altitude (Figure 5). The effect of increasing altitude is quite evident on both the family and species richness. The herbaceous species dominated the entire altitudinal gradient in terms of species richness, and with increasing altitude the trees and shrubs got disappeared. The climbers dominated the middle altitudinal range and were absent at both the extremes of the altitudinal gradient. Trees were represented in small numbers up to 3,000 m altitude whereas shrubs distributed up to 3,500 m and the maximum were found in the range around 2,501 ~ 3,500 m.

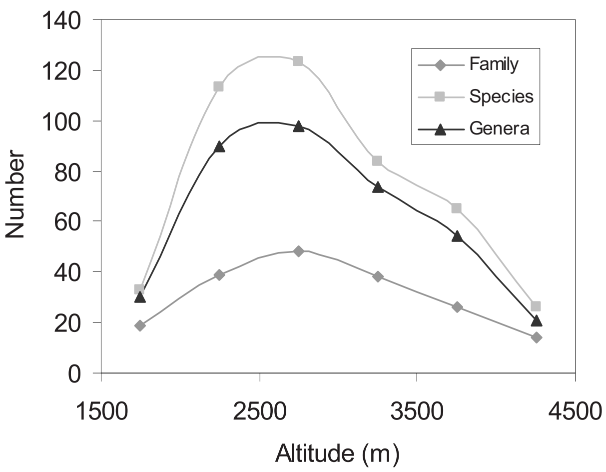

Figure 5 The distribution of plant taxa with increasing altitude

Species richness was found the highest in the mid-altitudinal ranges as also reported in Garhwal Himalaya and Grytnes and Vetaas (2002) and Grytnes (2003) in other temperate forests. The reduction in species in higher altitudinal gradient could be attributed to eco-physiological constraints, such as extremely low temperature, short period of growing season and geographical barriers. Further, the lower altitudes were in a regime of frequent anthropogenic disturbances, such as road construction, habitation and agricultural practices, which resulted in replacement of natural vegetation with man-made ecosystems consisting of plantations and agriculture. The maximum diversity at the mid-altitudes could be explained by Intermediate Disturbance Hypothesis (IDH) which stated that intermediate levels of disturbance maximize species diversity (Connell 1978). The number of species decreased towards the lower altitudinal gradient of the Bhabha Valley. It is due to the fact that a major part of the lower areas was disturbed due to intensive agriculture and dam construction. Furthermore, a majority of the species were exotic in this area. The species richness was higher in mid-elevation gradient, which corroborates the hard boundary theory (Colwell and Lees 2000, Grytnes and Vetaas 2002). The higher elevation gradients had less habitat diversity compared to mid elevation gradients consisting of arboreal forests, shrubs and climbers, which contributed to the increase in plant diversity. Above the timberline, only a few patches of shrubaceous vegetation and alpine meadows were found and they lacked moist environmental conditions to harbour rich plant diversity.

The number of species, genera and families were plotted against the altitudinal range of their occurrence. The decline in the three taxa along the altitudinal gradient displayed that most of the species had a narrow range of distribution (Figure 6). The replacement rate with the increasing altitude was calculated through β-diversity. The mid-altitudinal range showed maximum number of the species sharing with other altitudinal ranges. The highest altitudinal range shared fewer species with lower ranges and displayed high species replacement rate with increase in β-diversity (Table 2). The lower species replacement rate based on β-diversity at lower and mid-altitudinal gradients explained that higher altitudes had unique habitat and environmental conditions, and supported unique species. This was also supported from the percentage of the unique species at higher altitudinal ranges (Figure 7). Moreover, the mid altitudinal ranges favoured co-existence of a large number of species which were common to low as well as high altitudinal ranges (Lomolino 2001, WANG et al. 2002). The lower species richness at the highest altitudinal gradient might be due to the loss of habitat diversity (Colwell and Hurtt 1994, Bhattarai and Vetaas 2003), extreme environmental conditions and lack of adaptability of species to sustain life in hostile climates.

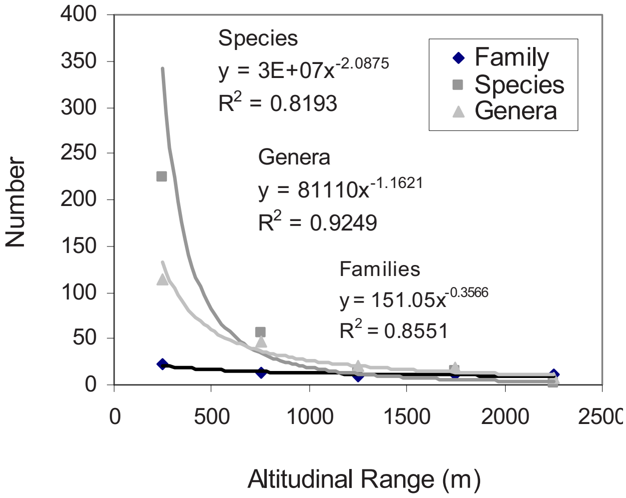

Figure 6 Range of distribution of plant taxa with respect to altitudinal gradient

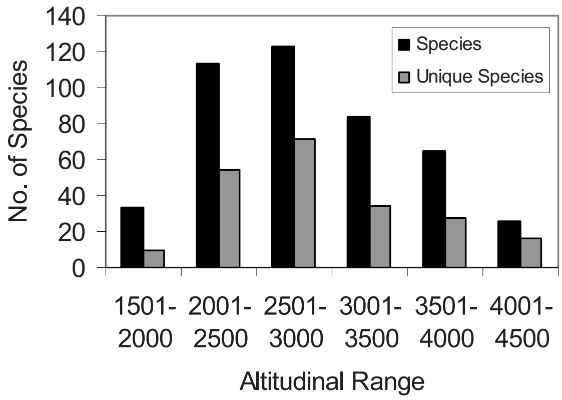

Figure 7 Distribution of unique species in the Bhabha valley

Table 2 Wilson and Schmida's β-diversity among different altitudinal classes

	Wilson and Schmida's (β_T)				
Altitudinal class (m)	2,001 ~ 2,500	2,501 ~ 3,000	3,001 ~ 3,500	3,501 ~ 4,000	4,001 ~ 4,500
1,501 ~ 2,000	0.740	0.910	0.949	0.980	1.000
2,001 ~ 2,500		0.754	0.797	0.865	0.957
2,501 ~ 3,000			0.807	0.894	0.946
3,001 ~ 3,500				0.638	0.927
3,501 ~ 4,000					0.824

3.4 Relationship between altitudinal gradient and species composition

The family Asteraceae was dominant in all the altitudinal ranges with hump-shaped relationship correlating with general trend of species richness along the altitudinal gradient. The members of Lamiaceae decreased with increasing altitude. The family Gentianaceae dominated in the higher altitudinal ranges and was either absent or represented with a very few species in the lower altitudinal ranges. The tree family Pinaceae was represented in the altitudinal gradient between 1,501 ~ 3,000 m. The members of Apiaceae dominated the middle altitudinal ranges and were found with a very few species in both the extreme altitudinal ranges. The extent of species distribution in the altitudinal gradient showed that none of the species distributed along the entire altitudinal range. *Minuartia kashmirica* was the only species distributing in the five altitudinal ranges (2,001 ~ 4,500 m). Besides, this species distributes in a wide range including China, Afghanistan and the entire Himalaya, and is adapted to grow under sub-tropical and temperate conditions (Polunin and Stainton 1984).

About 15 species were found distributing in three altitudinal ranges (3,000 ~ 4,500 m) (Figure 6). The maximum number of species were unique to the single altitudinal gradient with a restricted distribution. About 57 species distributed in 1,000 m range mostly from 1,501 to 2,500 m. The species composition along the altitudinal gradient showed adaptative nature of different families with increasing altitudes. Asteraceae showed a potential to grow in a wide range of environmental conditions and had high recruitment with resource limitation, thus dominating all the elevation gradients. The members of Gentinaceae largely distributed in the alpine areas of the temperate region in the world (Polunin and Stainton 1984) as also observed in the present study. The extent of distribution of species along the elevation gradient also displayed the varied adaptation of species with increasing altitude. *Minuartia kashmirica* (Caryophyllaceae) was the only species that showed a higher range of adaptation from 2,001 to 4,500 m.

3.5 Relationship between altitudinal gradient and rarity

A total of 18 species from the Bhabha Valley are reported to be threatened and 41 species are endemic which account for 5.75 % and 13.1 % respectively of the total species found in the valley (Table 1). All the threatened species were herbaceous and most of them were restricted to alpine meadows. Except *Polygonatum verticillatum*, *Rheum australe* and *Jurinea dolomiaea,* all the threatened species were also restricted to narrow altitudinal ranges. Most of the species had a narrow range of distribution. This may be due to variation in eco-physiological conditions of different altitudinal ranges favours different species composition. Most threatened species were found in the altitudinal range between 3, 001 ~ 3,500 m and none of them in the lowest altitudinal range (1,501 ~ 2,000 m). The occurrence of the threatened species at higher elevation ranges might be due to the reason that this area has been protected as a Wildlife Sanctuary and harbours many endemic species (Vetaas and Grytnes 2002). Further, these species have been protected from human interference by unapproachable and tough terrain. Among the alpine meadows, the lower ones were rich in threatened species. This might be due to the mass effect, where the merging of species distribution with environmental conditions favours rich plant diversity. Most of the threatened species belong to the vulnerable category. *Selinum vaginatum* is the only threatened species considered to be in low risk category. *Dactylorhiza hatagirea* is considered to be critically endangered according to the IUCN norms.

4 Conclusion

The so far unexplored Bhabha Valley in the western Himalaya was surveyed for its plant diversity. A total of 313 higher plant species in 204 genera and 68 families were recorded. A major part of the study area consisted of alpine meadows. 82 % of the plant species were herbaceous, and the others were trees (5 %), shrubs (9 %) and climbers (4 %). The valley with various habitats ranging from plantations to alpine meadows harboured 18 threatened and 41 endemic species generally occurring at higher altitudes. The maximum diversity was found at mid altitudes which could be attributed to 'Intermediate Disturbance Hypothesis'. The species area accumulation curve revealed that the valley could be harbouring about 500 species and negative log-log correlation was observed between the number of families and that of species. Most of the species had narrow range of distribution along the altitude. The β-diversity revealed that species replacement rate was more in higher altitudes.

Various anthropogenic activities like road construction, hydroelectric projects, tourism and over-exploitation of medicinal plants are posing a threat to the fragile ecology of the valley. The present study will be helpful in formulating strategies for proper conservation of the plant biodiversity of the Bhabha Valley.

Acknowledgements

The authors dedicate this manuscript in the memory of Dr. H.R. Negi, who pioneered this work. Thanks are also due to Dr. P.S. Ahuja, Director of Institute of Himalayan Bioresource Technology (CSIR) for providing facilities for this research and to Er. Amit Kumar for his help in this study. The financial assistance from the National Bioresource Development Board (Department of Biotechnology, Government of India) is duly acknowledged.

Table 1 List of species in the Bhabha Valley with life forms, threatened status and endemism in western Himalaya

Species	Family	Life form	Endemic & Threatened status (IUCN)
Abies pindrow Royle	Pinaceae	Tree	
Acer caesium Wall. ex Brandis	Aceraceae	Tree	Endemic & Vulnerable
A. pictum Thunb.	Aceraceae	Tree	
Achellia millefolium L.	Asteraceae	Herb	
Aconitum heterophyllum Wall. ex Royle	Ranunculaceae	Herb	Endemic & Endangered
A. violaceum Jacq. ex Stapf	Ranunculaceae	Herb	Endemic & Vulnerable
Adonis aestivalis L.	Ranunculaceae	Herb	
Ainsliaea aptera DC.	Asteraceae	Herb	
Ajuga parviflora Benth.	Lamiaceae	Herb	
Alliaria officinalis Andr. ex DC.	Brassicaceae	Herb	
Amaranthus paniculatus L.	Amaranthaceae	Herb	
Ampelocissus divaricata (Wall. ex Lawson) Planchon	Vitaceae	Climber	
Anaphalis adnata Wall. ex DC.	Asteraceae	Herb	
A. busua (Buch.-Ham. ex D.Don) DC.	Asteraceae	Herb	
A. nepalensis (Spreng.) Hand.-Mazz.	Asteraceae	Herb	
A. royleana DC.	Asteraceae	Herb	
A. triplinervis (Sims.) C.B. Cl.	Asteraceae	Herb	
Androsace globifera Duby	Primulaceae	Herb	
A. lanuginose Wall.	Primulaceae	Herb	
A. rotundifolia Hardwicke	Primulaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Anemone rivularis Buch.-Ham. ex DC.	Ranunculaceae	Herb	
Aquilegia fragrans Benth.	Ranunculaceae	Herb	Endemic
A. pubiflora Wall. ex Royle	Ranunculaceae	Herb	
Arabidopsis mollissima (C.A. Mey) N. Busch	Brassicaceae	Herb	
Arenaria festucoides Benth.	Caryophyllaceae	Herb	Endemic
A. orbiculata Royle ex Edgew. and Hk. f.	Caryophyllaceae	Herb	
Arisaema flavum (Forsk.) Schott	Araceae	Herb	
A. jacquemontii Blume	Araceae	Herb	
Artemisia gmelinii Webb ex Stechmann	Asteraceae	Herb	
A. japonica Thunb.	Asteraceae	Herb	Endemic
A. mreantha Wall. ex Bess.	Asteraceae	Herb	
A. nilagirica (C.B. Cl.) Pamp.	Asteraceae	Herb	
A. strongylocephala Ramp.	Asteraceae	Herb	
A. vestita Wall. ex DC.	Asteraceae	Herb	
Arundo donax L.	Poaceae	Herb	
Asparagus filicinus Buch.-Ham. *apud* D.Don	Liliaceae	Herb	
Aster falconeri (C.B. Cl.) Hutch.	Asteraceae	Herb	Endemic
Axyris hybrida L.	Chenopodiaceae	Herb	
Berberis chitria Edwards	Berberidaceae	Shrub	Endemic
B. lycium Royle	Berberidaceae	Shrub	Endemic
Bergenia ciliate (Haworth) Sternb.	Saxifragaceae	Herb	Endemic
Betula utilis D. Don	Betulaceae	Tree	Endangered
Bidens biternata (Lour.) Merill and Shreff.	Asteraceae	Herb	
Bistorta amplexicaulis (D.Don) Greene	Polygonaceae	Herb	
Blumea laciniata (Roxb.) DC.	Asteraceae	Herb	
Brachypodium sylvaticum (Huds.) P Beauv.	Poaceae	Herb	
Brassica oleracea L.	Brassicaceae	Herb	
Breea arvensis (L.) Less.	Asteraceae	Herb	

-Continued-

Species	Family	Life form	Endemic & Threatened status (IUCN)
Bromus pectinatus Thunb.	Poaceae	Herb	
Bupleurum falcatum L.	Apiaceae	Herb	Endemic
B. himalayense Klotzsh.	Apiaceae	Herb	
B. marginatum Wall. ex DC.	Apiaceae	Herb	Endemic
Calamagrostis pseudophragmites (Hall.f.) Koel.	Poaceae	Herb	
Caltha palustris L.	Ranunculaceae	Herb	
Campanula pallida Wall.	Campanulaceae	Herb	
Cannabis sativa L.	Cannabaceae	Herb	
Caragana brevispina Royle ex Benth.	Fabaceae	Shrub	
Carex wallichiana Sprengel	Cyperaceae	Herb	
Carpesium nepalense Lessing	Asteraceae	Herb	Endemic
Cassiopes festigiata (Wall. D.Don)	Ericaceae	Shrub	
Cedrus deodara (Roxb. ex D.Don) G.Don	Pinaceae	Tree	
Celtis australis L.	Ulmaceae	Tree	
Chenopodium album L.	Chenopodiaceae	Herb	
C. botrys L.	Chenopodiaceae	Herb	
C. foliosum (Moench) Aschers	Chenopodiaceae	Herb	
Chorispora sabulosa Camb.	Brassicaceae	Herb	
Cicerbita macrorhiza (Royle) G. Beauve.	Brassicaceae	Herb	
Clematis connata DC.	Ranunculaceae	Climber	
C. grata Wall.	Ranunculaceae	Climber	
Commelina bengalhensis L.	Commelinaceae	Herb	
Conyza Canadensis (L.) Cronquist	Asteraceae	Herb	
C. stricta Willd.	Asteraceae	Herb	
Corydalis cornuta Royle	Fumariaceae	Herb	
C. goviniana Wall.	Fumariaceae	Herb	Endemic
Corydalis meifolia Wall.	Fumariaceae	Herb	
Corylus jacquemontii Decne.	Betulaceae	Tree	Endemic

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Cotoneaster falconeri Klotz.	Rosaceae	Shrub	
Crepis multicaulis Ledeb.	Asteraceae	Herb	
Cuscuta reflexa Roxb.	Convolvulaceae	Climber	
Cyathula tomentosa (Roth) Moq.	Amaranthaceae	Herb	
Cymbopogon stracheyi (Hk. f.) Raizada and Jain	Poaceae	Herb	
Cynadon dactylon (L.) Persoen	Poaceae	Herb	
Cynoglossum glochidiatum Wall. ex Benth.	Boraginaceae	Herb	
C. *zeylanicum* (Vahl. ex Hornem) Thunb. ex Lehm.	Boraginaceae	Herb	
Cyperus niveus Retz.	Cyperaceae	Herb	
Dactylis glomerata L.	Poaceae	Herb	
Dactylorhiza hatagirea (D.Don) Soo	Orchidaceae	Herb	Critically Endangered
Daphne oleoides Schreb.	Thymelaeaceae	Shrub	
Delphinium brunonianum Royle	Ranunculaceae	Herb	
Descurainia Sophia (L.) Webb. Ex Prantl.	Brassicaceae	Herb	
Desmodium elegans DC.	Fabaceae	Shrub	Endemic
D. compacta Craib	Hydrangeaceae	Shrub	
Deutzia staminea R. Br. ex Wall.	Hydrangeaceae	Shrub	
Digitaria cillaris (Retz.) Koeler	Poaceae	Herb	
D. cruciata (Nees ex Steudel) A. Camus	Poaceae	Herb	
Dioscorea deltoidea Wall. ex Grisebach	Dioscoreaceae	Climber	Vulnerable
Dipsacus inermis Wall.	Dipsacaceae	Herb	Endemic
Draba lasiophylla Royle	Brassicaceae	Herb	
Echinocloa crus-galli (L.) P. Beauv	Cyperaceae	Herb	
Elaegnus parvifolia Wallich. ex Royle	Elaeagnaceae	Shrub	
Epilobium chitralense Raven	Onagraceae	Herb	
E. cylindricum D.Don	Onagraceae	Herb	
E. hirsutum L.	Onagraceae	Herb	
E. latifolium L.	Onagraceae	Herb	Endemic

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Erigeron alpinus L.	Asteraceae	Herb	
E. canadensis L.	Asteraceae	Herb	
Eriophorum comosum (Wall.) Wall. ex Nees	Cyperaceae	Herb	
Erodium cicutarium (L.) L'Herit ex Aiton	Geraniaceae	Herb	
Erysimum hieraciifolium L.	Brassicaceae	Herb	
E. melicentae Dunn.	Brassicaceae	Herb	
Euphorbia hispida Boiss.	Euphorbiaceae	Herb	
E. maddeni Boiss.	Euphorbiaceae	Herb	
Euphrasia himalaica Wettst.	Scrophulariaceae	Herb	
Fagopyrum esculentum (L.) Moench.	Polygonaceae	Herb	
Ferula jaeshkeana Vatke	Apiaceae	Herb	Vulnerable
Festuca undata Stapf	Poaceae	Herb	
Filipendula vestita (Wall. ex G. Don) Maxim.	Rosaceae	Herb	
Fragaria vesca L.	Rosaceae	Herb	
Galium aparine L.	Rubiaceae	Climber	
G. asperuloides Edgew.	Rubiaceae	Climber	
G. verum L.	Rubiaceae	Herb	
Gentiana marginata (D.Don) Griseb.	Gentianaceae	Herb	
G. tubiflora (D.Don) Griseb.	Gentianaceae	Herb	
G. venusta (D.Don) Griseb.	Gentianaceae	Herb	
Gentianella aurea (L.) H. Sm.	Gentianaceae	Herb	
Geranium aconitifolium L'Herit	Geraniaceae	Herb	
G. collinum Steph. ex Willd.	Geraniaceae	Herb	
G. himalayense Klotz.	Geraniaceae	Herb	
G. nepalense Sweet	Geraniaceae	Herb	
G. robertianum L.	Geraniaceae	Herb	
G. rotundifolium L.	Geraniaceae	Herb	
G. wallichianum D.Don ex Sweet	Geraniaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Geum elatum Wall. ex G. Don	Rosaceae	Herb	Endemic
G. roylei Bolle	Rosaceae	Herb	
G. urbanum L.	Rosaceae	Herb	
Hackelia uncinata (Royle ex Bth.) Fischer	Boraginaceae	Herb	
Heracleum lanatum Michx.	Apiaceae	Herb	Vulnerable
Herminium lanceum (Thunb. ex Swartz) Vuijk	Orchidaceae	Herb	
Hippophae rhamnoides L.	Elaeagnaceae	Shrub	
H. salicifolia D.Don	Elaeagnaceae	Shrub	Endemic
Impatiens racemosa DC.	Balsaminaceae	Herb	
I. scabrida DC.	Balsaminaceae	Herb	
I. thomsonii Hk. f.	Balsaminaceae	Herb	
Indigofera cedorurum Benth.	Fabaceae	Shrub	Endemic
I. dosua Buch.-Ham. ex D.Don	Fabaceae	Shrub	Endemic
I. heterantha Wall. ex Brandis	Fabaceae	Shrub	
Inula grandiflora Willd.	Asteraceae	Herb	
Ipomea purpurea (L.) Roth	Convolvulaceae	Climber	
Iris ensata Thunb.	Iridaceae	Herb	
Isolepis setacea (L.) R. Br.	Cyperaceae	Herb	
Juglans regia L.	Juglandaceae	Tree	Endemic
Juniperus communis L.	Cupresussaceae	Shrub	
J. indica Bertol.	Cupresussaceae	Shrub	
Jurinea dolomiaea Boiss.	Asteraceae	Herb	Vulnerable
Koeleria macrantha (Ledeb.) Schultes	Poaceae	Herb	
Lactuca dolichophylla Kitam.	Asteraceae	Herb	Endemic
L. macrorhiza (Royle) Hk. f.	Asteraceae	Herb	
L. orientalis Boiss.	Asteraceae	Herb	
Lathyrus emodi Wall. ex Fritch.	Asteraceae	Herb	
Leptorhabdos parviflora (Bth.) Bth.	Scrophulariaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Lindelofia anchusoides (Lind.) Lehm.	Boraginaceae	Herb	Endemic
Lomatogonium spathulata (Kerner) Fernald	Gentianaceae	Herb	
Lonicera myrtillus Hk. f. and Th.	Caprifoliaceae	Shrub	
Lotus corniculata L.	Fabaceae	Herb	
Malva neglecta Wallr.	Malvaceae	Herb	
Mecanopsis aculeate Royle	Papaveraceae	Herb	Endemic & Vulnerable
Mentha longifolia (L.) Huds.	Lamiaceae	Herb	
Micromeria biflora (Buch.-Ham. ex D.Don) Benth.	Lamiaceae	Herb	
Minuartia kashmirica (Edgew.) Mattf.	Caryophyllaceae	Herb	
Morina longifolia Wall. ex DC.	Morinaceae	Herb	
Myosotis silvatica Ehrh. ex Hoffm.	Boraginaceae	Herb	
Nepeta erecta (Bth.) Bth.	Lamiaceae	Herb	Endemic
N. eriostachya Bth.	Lamiaceae	Herb	
N. hindostana (Roth) Haines	Lamiaceae	Herb	
N. laevigata (D.Don) Hand.-Mazz.	Lamiaceae	Herb	
N. nervosa Royle ex Bth.	Lamiaceae	Herb	
Origanum vulgare L.	Lamiaceae	Herb	
Orobanche epithymum DC.	Orobanchaceae	Herb	
Oxalis corniculata L.	Oxalidaceae	Herb	
Oxybaphus himalaicus Edgew.	Nyctaginaceae	Herb	
Oxyria digyna (L.) Hill	Polygonaceae	Herb	
Papaver dubium L.	Papaveraceae	Herb	
Parnassia laxmanii Pallas ex Schultes	Parnessiaceae	Herb	
Pedicularis bicornuta Klotz. ex Klotz. and Garcke	Scrophulariaceae	Herb	Endemic
P. longiflora Rudolph	Scrophulariaceae	Herb	
P. pectinata Wall. ex Bth.	Scrophulariaceae	Herb	Endemic
P. porrecta Wall. ex Bth.	Scrophulariaceae	Herb	
Penisetum faccidium Griseb.	Poaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Phleum alpinum L.	Poaceae	Herb	
Phlomis bracteosa Royle ex Bth.	Lamiaceae	Herb	
Photinia nussia (Buch.-Ham ex D.Don) Kalkman	Rosaceae	Herb	
Picea smithiana (Wall.) Boiss.	Pinaceae	Tree	
Picrorrhiza kurruoa Royle ex Bth.	Scrophulariaceae	Herb	Endemic & Endangered
Pimpinella achilleifolia (DC.) C.B. Cl.	Apiaceae	Herb	
Pinus roxburghii Sargent	Pinaceae	Tree	
P. wallichiana Jackson	Pinaceae	Tree	
Piptatherum microcarpum (Pigl.) Tzod.	Poaceae	Herb	
Pisum sativum L.	Fabaceae	Herb	
Plantago depressa Willd.	Plantaginaceae	Herb	
Plectranthus rugosus Wall. ex Bth.	Lamiaceae	Shrub	
Pleurospermum brunonis (DC.) Bth. ex C.B. Cl.	Apiaceae	Herb	Endemic
P. stylosum Bth. ex C.B. Cl.	Apiaceae	Herb	
Podophyllum hexandrum Royle	Podophyllaceae	Herb	Endangered
Polygonatum geminiflorum Decne.	Liliaceae	Herb	
P. multiflorum (L.) All.	Liliaceae	Herb	Vulnerable
P. verticillatum (L.) All.	Liliaceae	Herb	Vulnerable
Polygonum affine D.Don	Polygonaceae	Herb	
P. aviculare L.	Polygonaceae	Herb	
P. convolvulus L.	Polygonaceae	Herb	
P. glaciale (Meissn.) Hk.f.	Polygonaceae	Herb	
P. hydropiper L.	Polygonaceae	Herb	
P. plebium R.Br.	Polygonaceae	Herb	
P. polystachya Wall. ex Meissn.	Polygonaceae	Shrub	
P. tortuosum D.Don	Polygonaceae	Herb	
Portulaca oleracea L.	Portulacaceae	Herb	
Potentilla argyrophylla Wall. ex Lehm.	Rosaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
P. atrosanguinea Lodd.	Rosaceae	Herb	
P. leucochroa Lindl.	Rosaceae	Herb	
P. nepalensis Hook.	Rosaceae	Herb	
P. sundaica (Blume) Kuntze	Rosaceae	Herb	
Primula denticulata Smith	Primulaceae	Herb	
P. *floribunda* Wall.	Primulaceae	Herb	Endemic
Prinsepia utilis Royle	Rosaceae	Shrub	
Prunus cornuta (Wall. Ex Royle) Steud	Rosaceae	Tree	
Pyrus malus L.	Rosaceae	Tree	
Quercus ilex L.	Fagaceae	Tree	
Ranunculus laetus Wall. ex D.Don	Ranunculaceae	Herb	
Rheum australe D.Don	Polygonaceae	Herb	Vulnerable
Rhodiola heterodonta (Hk. f. and Th.) A. Boriss.	Crassulaceae	Herb	
R. wallichiana (Hook.) Fu	Crassulaceae	Herb	
Rhododendron anthopogon D.Don	Ericaceae	Shrub	Vulnerable
Rorippa Montana (Hk. f. and Thomson) Small	Brassicaceae	Herb	
Rosa macrophylla Lindl.	Rosaceae	Shrub	Endemic
Rosularia alpestris (Kar. and Kir.) A. Boriss.	Crassulaceae	Herb	
Rubia cardifolia L.	Rubiaceae	Climber	
Rumex hastatus D.Don	Polygonaceae	Herb	
R. *nepalensis* Spreng.	Polygonaceae	Herb	
Salix elegans Wall. ex Anders.	Salicaceae	Tree	
S. flagellaris Anders.	Salicaceae	Shrub	
Salvia coccinea Buch'hoz ex Etlinger	Lamiaceae	Herb	
S. moorcroftiana Wall. ex Benth.	Lamiaceae	Herb	Endemic
S. mukerjea Bennet and Raizada	Lamiaceae	Herb	
S. nubicola Wall. ex Sw.	Lamiaceae	Herb	
Saussurea albescens (DC.) Sch.-Bip.	Asteraceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
S. auriculata (Sprengel exDC.)Schultz-Bipontinus	Asteraceae	Herb	
S. caespitosa Hk. f.	Asteraceae	Herb	
S. obovallata (DC.) Edgew.	Asteraceae	Herb	Vulnerable
S. simpsoniana (Field. and Gardn.) Lipsch.	Asteraceae	Herb	
Saxifraga jacquemontiana Decne.	Saxifragaceae	Herb	
S. parnassifolia D.Don	Saxifragaceae	Herb	
Scrophularia calycina Bth.	Scrophulariaceae	Herb	
S. suffruticosa Pennell.	Scrophulariaceae	Herb	
Sedum multicaule Wall. ex Lindl.	Crassulaceae	Herb	
S. oreades (Decne.) R. Hamet	Crassulaceae	Herb	
Selinum conifolium (Wall. ex DC.) Bth. and Hk.f.	Apiaceae	Herb	
S. tenuifolium L.	Apiaceae	Herb	
S. vaginatum (Edgew.) C.B. Cl.	Apiaceae	Herb	Endemic & Lower risk Least concern
S. wallichianum (DC.) Rhiz. At. Saxn.	Apiaceae	Herb	Endemic
Senecio desfontainei Druce	Asteraceae	Herb	
S. graciliflorus DC.	Asteraceae	Herb	
S. laetus Edgew.	Asteraceae	Herb	
Setaria pumila (Schumacher) Stapf et Hubbard	Poaceae	Herb	
Sibbaldia parviflora Willd.	Rosaceae	Herb	
Siegesbeckia orientalis L.	Asteraceae	Herb	
Silene vulgaris (Moench) Garcke	Caryophyllaceae	Herb	
Skimmia anquetilia Taylor and Airy Shaw	Rutaceae	Shrub	Endemic
Smilacina pallida Royle	Liliaceae	Herb	
Smilax vaginata Decne.	Liliaceae	Climber	
Solena amplexicaulis (Lam.) Gandhi	Cucurbitaceae	Climber	
Solidago virga-aurea L.	Asteraceae	Herb	
Sorbaria tomentosa (Lindl.) Rehder	Rosaceae	Shrub	
Sorbus lanata (Don) Schauer	Rosaceae	Shrub	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Stachys melissaefolia Bth.	Lamiaceae	Herb	
Strobilanthes atreporpureus Nees	Acanthaceae	Herb	
Swertia ciliata (G.Don) Burtt	Gentianaceae	Herb	
S. cordata (G.Don) C.B. Cl.	Gentianaceae	Herb	
S. petiolata Royle ex D.Don	Gentianaceae	Herb	
Tanacetum dolichophyllum (Kitamura) Kitamura	Asteraceae	Herb	
Taraxacum officinale Weber	Asteraceae	Herb	
Taxus baccata Hk. f.	Taxaceae	Tree	
Thalictrum chelidonii DC.	Ranunculaceae	Herb	
T. cultratum Wall.	Ranunculaceae	Herb	
T. reniforme Wall.	Ranunculaceae	Herb	
Themeda arundinacea (Roxb.) Ridley	Poaceae	Herb	
T. triandra Forsk.	Poaceae	Herb	
Thermopsis barbata Bth.	Fabaceae	Herb	
Thlaspi cardiocarpum Hk. f and Th.	Brassicaceae	Herb	
Thymus linearis Bth.	Lamiaceae	Herb	
Torilis japonica (Houttuyn) DC.	Apiaceae	Herb	
Tragopogon gracilis D.Don	Asteraceae	Herb	
Tricholepis elongata DC.	Asteraceae	Herb	Endemic
Trifolium repens L.	Fabaceae	Herb	
Trigonella emodi Bth.	Fabaceae	Herb	
Trillium govanianum Wall. ex D.Don	Liliaceae	Herb	
Trisetum spicatum (L.) Richt.	Poaceae	Herb	
Urtica ardens Link.	Urticaceae	Herb	
U. dioica L.	Urticaceae	Herb	
Valeriana jatamansi Jones	Valerianaceae	Herb	
V. stracheyi C.B. Cl.	Valerianaceae	Herb	Endemic
Verbescum thapsus L.	Scrophulariaceae	Herb	

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Species	Family	Life form	Endemic & Threatened status (IUCN)
Veronica beccabunga L.	Scrophulariaceae	Herb	
V. lanosa Royle ex Bth.	Scrophulariaceae	Herb	Endemic
Viburnum grandiflorum Wall. ex DC.	Caprifoliaceae	Shrub	
V. nervosum D.Don	Caprifoliaceae	Shrub	
Vicia bakeri Ali	Fabaceae	Herb	Endemic
V. *sativa* L.	Fabaceae	Herb	
Vigna vexillata (L.) A. Richard	Fabaceae	Herb	
Vincetoxicum hirundinaria Medikus	Asclepiadaceae	Herb	
Viola betonicifolia J. Smith	Violaceae	Herb	
V. canescens Wall.	Violaceae	Herb	
V. pilosa Blume	Violaceae	Herb	
Waldheimia glabra (Decne.) Regel	Asteraceae	Herb	
W. tomentosa (Decne.) Regel	Asteraceae	Herb	

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