Pak. J. Bot., 51(1), DOI: 10.30848/PJB2019-1(39)

SPATIAL PATTERNS AND DIVERSITY OF THE ALPINE FLORA OF DEOSAI PLATEAU, WESTERN HIMALAYAS

HAMAYUN SHAHEEN[1*], MUHAMMAD IBRAHIM[2] AND ZAHID ULLAH[3]

[1, 2]*Department of Botany, University of Azad Jammu and Kashmir Muzaffarabad*
[3]*Center for Plant Sciences and Biodiversity, University of Swat, KP, Pakistan*
[*]*Corresponding auther's email: hamayunmaldial@yahoo.com*

Abstract

The Western Himalayan alpines are among the most diverse ecological locations having diverse vegetation and provide a wide range of ecosystem services. The complex and dynamic Deosai Plateau is the World's 2nd highest plateau with an average elevation of 4500m. Current study was designed to investigate floristic diversity, phytosociological attributes, endemism and conservation status of flora of Deosai National Park, North Pakistan. Vegetation sampling was carried out by using random sampling through quadrat method at selected sites. A total of 8 plant communities were recorded from the area. The Floristic composition of present study consisted of 132 species belonging to 101 Genera and 41 families. Hemicryptophytes were recorded as the dominant life form followed by geophytes and Therophytes whereas Leptophylls and Nanophylls were dominant leaf spectra. The average value of Shannon diversity was calculated as 1.383 whereas Simpson diversity was 0.447. The calculated values of Evenness and richness were 0.882 and 1.185 respectively whereas the average maturity index was 30.27. A total of 63 plants species were found to be threatened having very low (<1%) importance values with 4 species recorded as critically endangered and endangered. Phytogeographic investigations revealed that 41 plant species (33%) were endemic to the Whole Himalayas, 18 species (14%) Endemic to Western Himalayas, 27 plants (22%) as tropical Asian and 34 plant species (27%) recorded as cosmopolitan. Principal component analyses (PCA) revealed Moisture and altitude as the key factors governing the species composition and community structure in the study area. Grazing pressure was observed as a major threat to the palatable species. It is recommended to extensively explore the population dynamics of endemic species as well as the spread of invasive species in DNP with the focus to conserve the precious threatened flora.

Key words: Himalayas, Alpine, Endemic, Ordination, Conservation.

Introduction

The alpine biomes are found in the mountainous region all around the World situated between perpetual snow zone and sub-alpine forests (Nautiyal *et al*., 2001). The Himalayas constitute a unique and dynamic biome being a globally recognized biodiversity ecoregion. The Himalayan alpine ecosystem having diverse vegetation with high levels of richness and endemism provide a wide range of ecosystem services and holds a key conservation priority in the region (Korner, 2003). Himalayan alpine biome is reported to have higher plant diversity than the average diversity index of world alpine biomes (Salick & Byge, 2008). The geographical coverage of Western Himalayan (WH) alpine zone is more extensive as compared to Eastern part also reflected by the higher number of vascular plants as 1800-1900 species in the Western Himalayas as compared to around 1200 species in the Eastern Himalayas (Rawat, 2007).

Distribution and diversity of alpine vegetation is governed by environmental variables spear headed by temperature, low water availability, rainfall, and high elevation. Alpine flora has adapted to the severe climatic conditions including high wind velocity, blizzards, scanty rainfall, low temperature, high ultraviolet (UV) radiation and avalanches (Tanner *et al*., 1998; Heaney and Proctor, 1989; Austrheim, 2005). They prominent floral elements of the Alpines include perennial grasses, sedges, cushion plants, mosses, forbs and lichens, well supported by useful aromatic, medicinal plants, and enriched animal forage alpine meadows. The plants are generally stunted, wooly or spiny, dwarfed, and develop a mosaic patch of special plant forms, possessing an early growth initiation with very short vegetative span and life cycle (Nautiyal *et al*., 2001). Communities show seasonal fluctuations, and are strongly influenced by the degree of periodic climatic phenomena (Cavaliere, 2009).

The soils of the alpine regions are of coarser nature, mixed with stones and gravel and characterized by weak secondary mineralizaton and high percentage of soil organic carbon due to slow rate of decomposition (Khan, 2010). Water availability is highly variable in the alpine regions governed by geographical variables including altitude, aspect and degree of slope steepness (Austrheim, 2005; Eriksson, 2001). The vegetation exhibits a pronounced early growth initiation and short growing season dominated by the Hemicrptophtes and Chamaephytes being the indicators of harsh climatic conditions with extremely cold climate and limited growth period (Shankar & Singh, 1995).

The Himalayan alpines are among the most vulnerable regions facing a serious threats from world climate change with serious implications for the sustainability of this unique biodiversity hotspot (Peer *et al*., 2007). The diversity and ditribution of alpine vegetation in Western Himalayan alpine rangeland has not received due attention of researchers, and hence gaps in information and knowledge on these high elevated natural environments ecosystem still persist (Rawat & Adhikari, 2005). Deosai National Park (DNP) is a in the North Pakistan is the world's 2nd highest alpine plateau and has its isolated geography, exciting location and diverse climatic condition with very peculiar highly endemic and unique vegetation. Deosai National Park ecosystem provides valuable services to the local communities in terms of grazing area, medicinal and aromatic plants, fresh water and fisheries. Nearly fifty different neighboring communities have traditional rights of grazing inside the protected area along with nomadic herdsmen in summer (Khan *et al*., 2010; Akhlas, 2009).

It is critically important to investigate the current status of the floral wealth of DNP for proper management and better understanding of alpine grassland in terms of conservation and sustainability along with social and cultural significance. Current study was carried out with the specific objectives of investigating the floristic composition, phytodiversity, community structure and Phytosociological attributes of the DNP along with analyzing the effect of environmental variables on the alpine plant communities.

Materials and Methods

Study area: Deosai plateau lies in the Western Himalayan range of North Pakistan at an elevational range of 3500 to 5000 m latitudinally at 35^0.02' N and longitudinally at 075^0.25' E between Skardu and Astore district, Gilgit Baltistan Province. Deosai was declared as National Park in 1993 to protect the natural, biological and ecological habitat balance of this fragile ecosystem and to conserve critically endangered Brown Bear of Great Himalayas with a total protected area of 2950 km^2 (Fig. 1). Deosai has long winter season spaning more than half of the year from September to May with a 6–8 m deep snow and a short summer season from Mid-May to September. Mean Daily temperature of the DNP meadow ranges from –20°C in winters to 9°C in summers; having an annual precipitation of 510 mm to 750 mm (Nawaz, 2007; Pak-Met, 2016). DNP has a rich hydrology with four large water bodies including 3 streams, Sheosar Lake and extensive marshy basins.

Sampling methodology: Study was conducted during May-August 2016. Eight different sampling sites were chosen for vegetation sampling selected with respect to topography, altitude, hydrology, and disturbance to get a true image of whole vegetation and enlist maximum species composition. Primary phytosociological data like density, frequency, cover was recorded by using random quadrate method with Square shaped quadrats of 1 m^2 following standard protocol (Cox, 1976). Primary data was used to quantify the vegetation attributes including Importance value index, Species composition, Evenness, Richness, Similarity Index, Degree of maturity, Life form and Leaf spectrum (Mueller-Dombois & Ellenberg, 1974). Collected plants were preserved and identified following flora of Pakistan (Nasir & Ali, 1970, 1980; Ali & Qaisar, 1993; Ali & Nasir, 1989). The phytogeographical analysis of the flora was performed to classify the floral elements on the basis of continental origion following Richardson *et al*., (2000) and Pysek *et al*., (2004).

The geographic characteristics including slope, aspect, topography, coordinates and altitude along with the disturbances like grazing and erosion were recorded at site. The data was statistically analyzed by using Principal Component Analysis to reveal the major trends in community structure in relationship with prevelant environmental variables (McCune & Mefford, 2005).

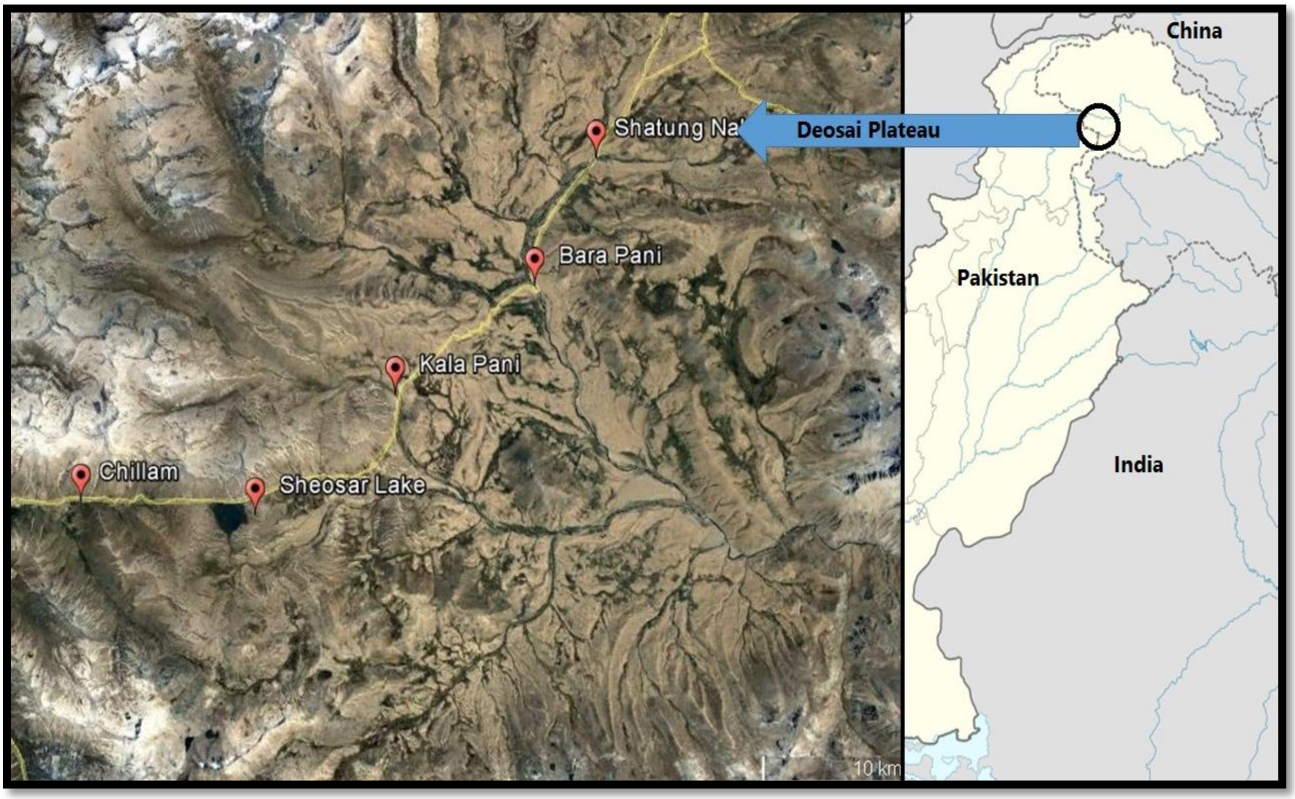

Fig. 1. Map of the study area and satellite imagery of the sampling sites in Western Himalayas.

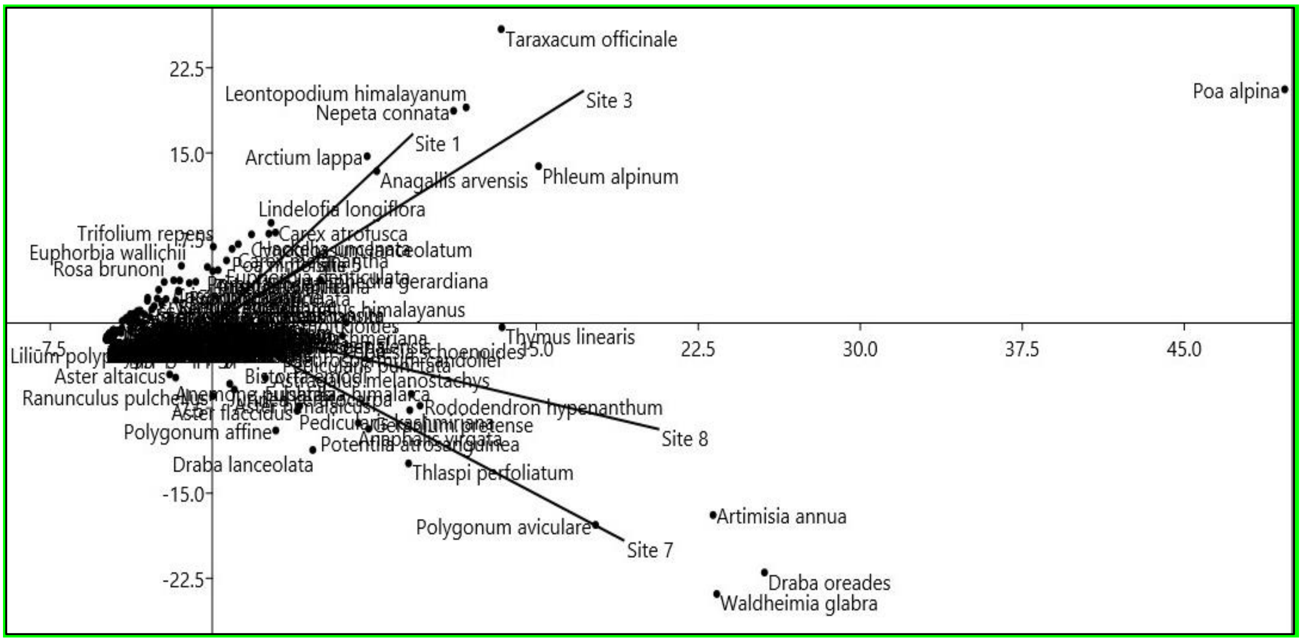

Fig. 2. Principal Component Analysis (PCA) Biplot of the species data.

Results

The present study was conducted to determine the diversity and distribution of alpine vegetation in DNP. A total of 132 plants species belonging to 41 families and 101 Genera were recorded with 37 Angiosperm and 2 Gymnospermae families whereas a single representative member of Bryophytes, Pteridophytes, Moss and lichen were also recorded. Asteraceae was the most dominant family with 17 representative members followed by Polygonaceae (12 species), Ranunculaceae (8 species); and Rosaeae and Scrophureaceae (7 species each) (Fig. 2). The average IVIs revealed that *Poa alpina* was the overall dominant species having average value of 18.28 followed by *Phleum alpina* (8.91); *Taraxacum tibetanum* (7.74), *Kobresia schoenoides* (7.44), *Draba oreades* (7.16) and *Nepeta connata* (7.13) (Table 1). Hemicryptophytes were dominant life form comprising 54% of the total flora followed by Geophytes (19%), therophytes (15%), Chaemophytes (9%) and cryptophytes (2%). Epiphytes, Bryophytes and lichens were also recorded as 0.75% each (Fig. 2). Nanophylls were the dominant leaf spectrum making 48% followed by Leptophylls (29%), Microphylls (20%) and Mesophylls (20%) respectively (Table 1).

A total of eight communities were identified from the three major zones of study area of DNP in the altitudinal ranges of 3700 up to 4200m established on the basis of dominant species having highest importance values namely *Poa-Draba-Rhodiola*, *Waldheimia-Artimisia-Polygonum*, *Salix-Carex-Kobresia*, *Kobresia-Primula-Primula*, *Allium-Phleum-Carex*, *Poa- Anaphalis-Leontopodium*, *Caltha-Carex-Pedicularis* and *Taraxacum-Nepeta-Poa* Communities respectively.

The study sites showed an average species count of 42 with a maximum of 61 at site 6 whereas a minimum of 22 at site 7. The average value of Simpson's diversity was calculated as 0.44 with a maximum of 0.734 at Sites 3 and 5 each and a minimum of 0.26 at site 4 whereas the Shannon-Wienner's diversity index averaged as 1.41 with a maximum of 1.72 at site 6 and a minimum of 1.06 at site 8. The average value of species richness and eveness were calculated as as 1.15 and 0.89 respectively. The communities exhibited very low value for the Maturity Index as 30.9% (Table 2).

Phytogeographic analysis of the local flora revealed Eight species (14%) were recorded as Endemic to Western Himalayas including *Alchemilla cashmeriana*, *Astragalus himalayanus*, *Delphinium cashmerianum*, *Euphrasia himalaica*, *Pulsatilla wallichiana*. The floral elements having Central and Eastern Himalayan origin were reported to be 5 in number including *Sassuria lappa*, *Heraccleum candicans*, *Aconitum hterophyllum* etc. Major proportion (33%) of the flora comprising 41 plant species (33%) were recorded as Endemic to the whole Himalayas including the keystone endemic genera as *Aconitum*, *Carex*, *Primula*, *Rhodiola*, *Bistorta* and *Leontopodium*. About 34 plant species (27%) were documented as cosmopolitan Worldwide where as 27 plants (22%) were reported to be as cosmopolitan to Asia mostly comprsing the widespread and abundant taxa including several invasive species as well.

PCA ordination biplot revealed strong correlation between two environmental gradients Moisture and altitude with floral distribution and vegetation pattern in the study area. Profound influence of moisture was revealed by PCA biplot divideding the flora of DNP into two mian groups, Dry sites and moist sites. Four moist sites (Site 2, 4, 5 and 6) were clustered at the centre of the biplot whereas four dry sites (1, 3, 7 and 8) were further separated on different axes on the basis of altitudinal variation. Two comparatively lower altitudinal (3770-3800) dry sites 1 and 3were placed towards 2nd axis with indicator species including *Anaphalis arvensis*, *Arctium lappa*, *Leontopodium himalayanum*, *Nepeta connata*, *Phleum alpinum* and *Taraxacum tibetanum.* The 2nd group comprised of the dry sites 7 and 8 with higher altitudes of 3900-4000m ploted along 1st axis with associated species *Artemisia annua*, *Draba oreades*, *Polygonum aviculare*, *Thlaspi perfoliatum* and *Waldheimia glabra.* It can be inferred that the moisture masked the influence of other environmental gradients. Altitude variations also affect the vegetation pattern at dry sites. *Poa alpina* was identified as the most dominnat element in the study area placed away from central axis due to its uniform abundance in all communities (Fig. 2).

Table 1. Species composition, Biological spectra and altitudinal range of the flora of Deosai National Park.

Sr. No.	Species Name	Family	Altitude	Life form	Leaf spectrum	Ave IVI
1.	*Acantholimon lycopodiodes* (Girard) Bioss	Plumbaginaceae	4150-4170	Ch	Na	0.84
2.	*Achillea millefolium* L.	Asteraceae	3780-4170	He	Na	1.13
3.	*Aconitum chasmanthum* Stapex Holm	Ranunculaceae	3770-4170	Ch	Mi	1.75
4.	*Aconitum heterophyllum* Wall.Atis.	Ranunculaceae	4150	Ch	Mi	1.46
5.	*Alchemilla cashmeriana* Rothm	Rosaceae	3880	Ch	Na	0.40
6.	*Allium fedtschenkoanum* Regel.	Amaryllidaceae	3880-4170	Cr	Na	3.89
7.	*Alopecurus aequalis* Sobol.	Poaceae	3880	He	Na	0.32
8.	*Anaphalis arvensis* L.	Asteraceae	3790-4150	Th	Na	4.66
9.	*Anaphalis virgata* Thoms.	Asteraceae	3910-4170	He	Le	3.50
10.	*Anemone polyanthes* D.Don	Ranunculaceae	3880	Ge	Na	0.64
11.	*Anemone pulsatilla* L.	Ranunculaceae	3907	He	Na	0.77
12.	*Aquilegia fragrans* Bth.	Ranunculaceae	3770-3880	Ge	Me	1.68
13.	*Arabis tibetica* Hook. Thomus	Brassicacaceae	4150	Th	Le	0.41
14.	*Arctium lappa* L.	Asteraceae	3780-4170	Ch	Na	3.83
15.	*Artimisia annua* L.	Asteraceae	3770-4170	He	Na	7.53
16.	*Aster altaicus* Willd.	Asteraceae	3910-3990	He	Mi	0.70
17.	*Aster flaccidus* Bunge	Asteraceae	3880-3910	He	Mi	2.14
18.	*Aster himalaicus White*	Asteraceae	3770-4150	Th	Mi	2.42
19.	*Astragalus himalayanus* Klotzch	Fabaceae	3770-4170	He	Le	2.92
20.	*Astragalus melanostachys* Bth.	Fabaceae	3770-4170	He	Le	4.09
21.	*Bistorta affinis* D.Don	Polygonaceae	3770-4150	Ch	Na	2.40
22.	*Bistorta emodi* (Meisn.) Petrov.	Polygonaceae	3770-4170	Ge	Na	2.90
23.	*Borago officinalis* L.	Boraginaceae	3780-4200	Th	Le	1.06
24.	*Bupleurum thomsonii* Clarke.	Apiaceae	3770-3880	He	Le	1.10
25.	*Caltha alba* Cambess.	Ranunculaceae	4150	He	Me	2.82
26.	*Campanulla aristata* Wall.	Campanulaceae	3880	Ch	Mi	0.29
27.	*Capparis himalayensis* Jafri.	Capparaceae	4170	Np	Mi	0.64
28.	*Carex atrofusca* Schkuhr.	Cyperaceae	3770-4170	He	Mi	3.93
29.	*Carex infuscata* Nees.	Cyperaceae	3770-3780	He	Mi	3.72
30.	*Carex kashmirensis* C.B Clarke	Cyperaceae	3880	He	Na	0.63
31.	*Carex melanantha* C.A.Mey	Cyperaceae	3770-4170	He	Na	4.08
32.	*Cerasticum cerastoides* (L.) Britton	Chenopodiaceae	3780	Th	Na	0.45
33.	*Chenopodium album* L.	Chenopodiaceae	3780-4170	Th	Na	0.77
34.	*Chenopodium foliosum* Moench	Chenopodiaceae	3880	Th	Na	0.71
35.	*Cicer microphyllum* Roylex Benthum	Fabaceae	4150-4170	He	Le	1.37
36.	*Cortia depressa* (D.Don) Norman	Apiaceae	3770-3880	He	Na	0.94
37.	*Corydalis diphylla* Wall.	Papaveraceae	3880	Th	Na	0.40
38.	*Cotoneaster humilis* Dunn.	Rosaceae	3780	Np	Na	0.59
39.	*Corispermum tibeticum* Iljin	Chenopodiaceae	4170	Th	Mi	0.34
40.	*Cuscuta reflexa* Roxb.	Convolvulaceae	3780	Li	Na	0.94
41.	*Cynoglossum lanceolatum* Forsk	Boraginaceae	3780-3800	He	Na	2.14
42.	*Dactylorhiza glabra* DC	Orchidaceae	3770	Ge	Me	0.77
43.	*Dactylorhiza hatagirea* (D.Don) soo.	Orchidaceae	4150	Ge	Na	0.46
44.	*Delphinium cashmerianum* Royle.	Ranunculaceae	3770	He	Le	0.47
45.	*Dianthus royleanum* Hausskn	Caryophylaceae	3780-4170	Ch	Le	0.94
46.	*Draba lanceolata* Royle.	Brassicacaceae	3910	He	Le	2.22
47.	*Draba oreades* Schrenk ex Fisch.	Brassicacaceae	3880-3990	He	Le	7.16
48.	*Ephedra gerardiana* Wall.	Ephedraceae	3770-3990	Ch	Na	3.25
49.	*Epilobium royleanum* Hausskn	Onagaraceae	3780	He	Mi	0.96
50.	*Erysimum melicentae* Dunn	Brassicacaceae	3770-3880	Th	Na	0.38
51.	*Euphorbia denticulata* Lam.	Euphorbiaceae	3770-3790	He	Na	1.41
52.	*Euphorbia wallichii* Hook f.	Euphorbiaceae	3770-3780	Ch	Na	1.88
53.	*Euphrasia himalaica* Wettst	Orobanchaceae	3990	He	Na	2.14
54.	*Fumaria indica* Pugsely	Papaveraceae	4150-4170	Th	Na	1.58
55.	*Gagea lowariensis* Pascher	Lilliaceae	3880	Ge	Na	1.85
56.	*Galium aparine* L.	Rubiaceae	3790	Th	Na	0.30
57.	*Galium boreale* L.	Rubiaceae	3770-3780	He	Le	0.95
58.	*Geranium pratense* L.	Geraniaceae	3770-4170	He	Mi	3.12
59.	*Hackelia uncinata* Royl. Ex Bath	Boraginaceae	3770-4150	Ge	Mi	2.59
60.	*Helictotrichon paratense* (L.) Pilg	Poaceae	3770	He	Le	0.27
61.	*Heracleum candicans* Wall. Ex DC.	Apiaceae	3770-4170	Ge	Me	1.13
62.	*Hylotelephium ewersii* Ledeb	Crassulaceae	3770	He	Na	0.58
63.	*Iris hookeriana* Foster.	Iridaceae	3770-3800	Ge	Na	1.47
64.	*Gentiana cachemirica* Decne.	Gentianaceae	3770-4170	Ge	Mi	1.53
65.	*Juncus maritimus* L.	Juncaceae	3770	He	Na	1.64

Table 1. (Cont'd.).

66.	*Juncus articulatus* L.	Juncaceae	3770	He	Le	0.88
67.	*Juniperus squamata* Lamb.	Cupressaceae	4170	Np	Na	0.21
68.	*Jurinea ceratocarpa* Bth	Asteraceae	3880-3990	Ge	Le	1.90
69.	*Kobresia schoenoides* Boeck.	Cyperaceae	3880-4170	He	Na	7.44
70.	*Lagotis kashmeriana* (Royle) Rupr	Scrophularaceae	3880-4170	Ge	Mi	2.93
71.	*Leontopodium alpinum* Hook	Asteraceae	4170	Th	Na	0.73
72.	*Leontopodium himalayanum* DC	Asteraceae	3780-3880	Th	Na	5.17
73.	*Lilium polyphyllum* D.Don	Liliaceae	3880-3990	Ge	Na	1.26
74.	*Lindelofia longiflora* (Benth) Bail.	Boraginaceae	3790-4170	He	Mi	3.94
75.	*Lonicera coerulea* L.	Caprifoliaceae	4170	Np	Mi	1.02
76.	*Medicago falcata* L.	Fabaceae	4170	He	Na	0.74
77.	*Nepeta connata Royle.*	Lamiaceae	3770-4170	He	Le	7.13
78.	*Oxalis corniculata* L.	Oxalidaceae	3880-4170	Th	Na	2.64
79.	*Papaver nudicaule* L.	Papaveraceae	3880	He	Na	0.51
80.	*Parnassia palustris* L.	Celastraceae	3880	He	Na	0.30
81.	*Parnassia nubicola* wall. ex Royl.	Celastraceae	3880	He	Na	0.30
82.	*Pedicularis kashmiriana* Penn.	Orobanchaceae	3770-3900	He	Le	4.33
83.	*Pedicularis punctata* Decne	Orobanchaceae	3770-4170	He	Le	2.56
84.	*Phleum alpinum* L	Poaceae	3770	He	Na	8.91
85.	*Pleurospermum candollei* Bth	Apiaceae	3990	He	Mi	1.93
86.	*Poa alpina* L.	Poaceae	3770-4170	He	Li	18.28
87.	*Poa nimoralis* L.	Poaceae	3770-4170	He	Le	3.45
88.	*Polygonum affine* D. *Don*.	Polygonaceae	3900	Ge	Le	1.83
89.	*Polygonum aquileum* L.	Polygonaceae	3880	Ge	Me	0.44
90.	*Polygonum arenastrum* Boreau	Polygonaceae	4150	Ge	Mi	1.47
91.	*Polygonum aviculare* L.	Polygonaceae	3790-4170	He	Le	5.66
92.	*Polygonatum verticilatum* L.	Asparagaceae	3770-4170	Ge	Le	1.12
93.	*Potentila atrosanguinea* W.Lodd	Rosaceae	3770-4170	He	Mi	3.75
94.	*Potentila inserina* L.	Rosaceae	3900-4170	He	Na	3.44
95.	*Primula denticulata* Wight	Primulaceae	3770-4170	He	Mi	3.64
96.	*Primula elliptica* Royle	Primulaceae	3770-4170	He	Mi	5.28
97.	*Primula rosea* Royle	Primulaceae	3770-4170	He	Le	4.99
98.	*Prunella vulgaris* L.	Labiateae	3770	He	Le	0.49
99.	*Pseudomertensia moltkioides* Kazmi	Boraginaceae	3900-4170	Ch	Mi	0.93
100.	*Pulsatilla wallitiana* (Royl.) Ulbr	Ranunculaceae	3790	Ge	Mi	1.29
101.	*Ranunculus pulchellus* C.A. Mey	Ranunculaceae	3880	He	Mi	1.39
102.	*Rheum emodii* Wall.ex (Ch)	Polygonaceae	3790-4170	Ge	Ma	1.94
103.	*Rheum tibeticum* Maxim.	Polygonaceae	3790-4170	Ge	Ma	2.41
104.	*Rhodiola tibetica* (Hook*)* S.H	Crassulaceae	3880-4170	Ge	Le	1.32
105.	*Rhodiola heterodonta* (Hook).Boris	Crassulaceae	3770-4170	Ge	Le	0.53
106.	*Rododendron hypenanthum* Balf	Ericaceae	4170	Np	Mi	3.53
107.	*Rorippa montana* Wall ex Hook	Brassicacaceae	3880	Th	Na	0.32
108.	*Rosa brunoni* Lindle.	Rosaceae	3770-4170	Np	Le	1.80
109.	*Rubus saxitalis* L.	Rosaceae	3770-3780	Np	Me	0.78
110.	*Rumex nepalensis* Sprenge	Polygonaceae	3780-4170	Ge	Me	3.45
111.	*Rumex patentia* L. Var Tibetica Retch	Polygonaceae	3770-4170	Ge	Me	0.52
112.	*Salix flebellaris* Anders.	Salicaceae	3770-4170	Np	Mi	5.71
113.	*Salix himalensis* Fold.	Salicaceae	3770-3880	Np	Mi	1.61
114.	*Saussurea fastuosa* (Decne.) Sch.Bip.	Asteraceae	3770	He	Me	0.52
115.	*Saussurea costus* (Falc.) Lipsch.	Asteraceae	3780-3880	He	Ma	0.96
116.	*Saxifraga flagellaris*	Saxifragaceae	3800-4150	Ge	Mi	0.79
117.	*Scorzonara virgata* DC.	Asteraceae	3780-4170	He	Le	1.85
118.	*Scrophularia decomposita* Royle	Scrophularaceae	3770-3790	He	Na	1.01
119.	*Sedum ewersii* Ledeb	Crassulaceae	3770-4150	He	Mi	1.58
120.	*Sedum oreades* (Dcne) Hamet	Crassulaceae	4180	He	Na	0.37
121.	*Sibaldia cunneata* Kze.	Rosaceae	3770-4170	Ch	Mi	1.34
122.	*Silene gonosperma* (Rupr) Bocquet	Caryophyllaceae	4170	He	Na	0.40
123.	*Swertia allata* C.B. Clarke	Gentianaceae	3770-4170	Th	Na	3.20
124.	*Taraxacum obovatum* (Wild) DC.	Asteraceae	3770-4150	Ch	Mi	7.74
125.	*Taraxacum tibiticum* Hand-Mazz	Asteraceae	3880	Ch	Mi	0.48
126.	*Thelepogon elegans* Roth	Poaceae	4150-4170	Th	Na	0.59
127.	*Thlaspi perfoliatum* L.	Brassicacaceae	3880-3990	He	Le	3.45
128.	*Thymus linearis* Benth.	Lamiaceae	3770-4170	He	Na	5.55
129.	*Trifolium repens* L.	Fabaceae	3770-4170	He	Mi	4.12
130.	*Verbascum thapsus* L.	Scrophulariaceae	3780	Th	Me	0.50
131.	*Veronica purpusilla* Bioss.	Scrophulariaceae	3770	He	Na	0.55
132.	*Waldheimia glabra* Regl.	Asteraceae	3880-4170	He	Na	7.80

Table 2. Phytosociological attributes of alpine communities at the studied sites.

Community name	Altitude	Species diversity		Species richness	Species evenness	Degree of maturity	Number of spp.
		Simpson	Shannon				
Taraxacum-Nepeta-Poa Community	3781	0.340	1.438	1.55	0.897	25.50%	40
Caltha-Carex-Pedicularis Community	3775	0.281	1.561	1.40	0.918	30.40%	50
Poa- Anaphalis -Lentopodium Community	3790	0.733	1.238	0.80	0.874	38.46%	36
Allium- Phleum-Carex Community	4170	0.258	1.610	1.29	0.917	22.08%	57
Kobresia-Primula-Primula Community	4153	0.733	1.373	0.95	0.851	30.24%	41
Salix-Carex-Kobresia Community	3880	0.161	1.710	1.60	0.957	28.85%	61
Waldheimia-Artimisia-Polygonum Community	3907	0.510	1.271	0.77	0.946	36.36%	22
Poa-Draba-Rhodiola Community	3987	0.500	1.057	0.83	0.808	35.65%	23

Discussion

Himalayas are known to be diverse vegetation centre of the world with more than 18,440 endemic plant species (Maikhuri *et al.*, 2000). The distinctive geographical region of the Deosai plains in the western Himalayas exhibits great levels of phytodiversity, endemism and species richness with high conservation status (Karan, 2006). The alpine flora comprised of 41 families consisting of 132 species and 101 genera with the clear dominance of Asteraceae, Polygonaceae, Ranunculaceae, Rosaeae and Scrophureaceae making up to 38% of total flora. The dominance of the Asteraces and Rosaecea in the alpine ecosystems is well reported from the Himalayan highlands due to their phytogeographic origion and specialized niches adapted for the highland climates (Mashwani *et al.*, 2011). The ephemeral species like *Poa alpine*, *Phleum alpine*, *Taraxacum tibetanum*, *Kobresia schoenoides*, *Draba oreades* and *Nepeta connata* with short life spans showed widerspread abundance and dominance in the communities due to morphological, physiological and genetic adaptations playing key role in the rapid diversification and dominance in the extreme cold environment (Wesche *et al*., 2000).

The analysis of life form spectrum of the local flora revealed dominance of the hemicryptophytes and therophytes in an overlapping and loose continuum. These life forms are well adapted to the environmental severities having reduced life cycles and phenotypic plasticity (Khan *et al.*, 2016; Rahman *et al*., 2016). *Cuscuta reflexa* was the only epiphyte found in the study area indicating the scarcity of bigger host plants. Leptophylls and nanophylls were dominant leaf spectra which make up to the 72% plants species of the study area. Species having small leaves are generally characteristics of dry, harsh and adverse habitats acclimatized to water scarcity (Nasir & Sultan, 2002; Sher & Khan, 2007).

Moisture appeared to be the key limiting factor in the region controlling the distribution and diversity of the flora. Approprate moisture level assists vegetation growth by providing an adequate water supply under a challenging climate and throughout water-limited rangelands (Khan *et al*., 2015; Bai *et al*., 2004). The highest values of diversity and richness were exhibited by the moist sites also verified by the ordination analysis. The adverse effects of anthropogenic disturbances as grazing, fodder and medicinal plant collection are also minimized in the high moisture sites (Yang & Piao, 2006). The alpine vegetations shows mosaic scrap of stunted, small dwarfed, spiny or wooly vegetation as an adaptation to extreme environmental constrains and harsh climatic (Zhang *et al.*, 2015). The dry sites were characterized by significant count of Therophytes and geophytes in biospectrum. Altitude is another important factors that appeared to be controlling the distribution of alpine flora in DNP (Barrera *et al.*, 2000). Species diversity peaked at the intermediate altitude sites corresponding to an optimal combination of environmental resources. Elevation provides a complex gradient where ecological factors vary in different spatial scales, and plants respond to those different combinations of ecological factors (Alard & Poudevigne, 2000).

The recorded values of Diversity in the present study in the DNP was lower than results of similar investigationsin in the aplines of Indian, Napelese and Chinese Himalayas (Samant *et al.*, 1998; Shaheen *et al.*, 2011; Tambe & Rawat, 2010). The low diversity and richness values can be attributed to relatively higher altitude of the DNP leading to ecological constraints such as low temperature, less water availability, reduced growing season and low productivity (Magurran, 2004). The evenness values in the recorded communities showed antagonistic changes with increase in the number of species as well as diversity; also supported by the findings of Weiher & Keddy (1999); Wilsey *et al.*, (2005) and Manier & Hobbs, (2006).

The results of the current study showed an increase in the species richness with moderate grazing. Moderate grazing often is expected to promote plant community diversity and richness by reducing the opportunity for competitive exclusion of subdominant species and increased light availability (Gibson, 2009; Borer *et al.*, 2014). The positive correlation between controlled grazing and diversity has also been reported in in the alpine pastures of Tibetan plateau (Yang & Piao, 2006). Different magnitudes of the grazing intensity also contributed towards similarity in the species composition between the plant communities. The communities 7 and 8 characterized with moderate grazing showed high values for the similarity index (>50) due to dominance of unpalatable species. Whereas community 4 and 5 with low grazing pressure also showed high similarity due to low disturbance correlated with maximum diversity and richness.

The values of the maturity index in the studies plant communities ranged between 25-35%, far below the 60% benchmark with none of the communities qualified as mature. The natural balance of frail alpine vegetation is regularly disturbed by harsh climatic conditions combined with the anthropogenic disturbances in already short growing season, which restrains these ecosystems to achieve climax stage (Tiessen & Wu, 2002). This unique and diverse alpine region is likely to suffer critical species losses, especially the endemic alpine plants due to over grazing medicinal plant collection, introduction of invasive species as well as habitat degradation due to impacts of climate change (Panthi *et al*., 2007. This fact was evident from the prevalence of 27% cosmopolitan species recorded from the DNP. The 4 plant species enlisted in the IUCN threatened taxa including *Saussurea lappa*, *Aconitum chasmanthum*, *Aconitum heterophylum* and *Lilium polyphyllum* were recorded with having low importance values (<1%) indicating the potential risk of local extinction from the region; and reflect the need for immediate conservation measures (IUCN, 2017).

Current research revealed significant correlation between the distribution and status of the alpine flora of DNP with enviroenmnatal variables like moisture and altitude and management practices such as grazing. The population dynamics of the endemic and threatened floral elements needs to be explored extensively with prime conservational priorities. It is recommended to sustaibly manage the precious and diverse alpine flora of DNP by regulating the intensity of grazing pressure and controlling habitat degradation.

References

Akhlas, M. 2009. Transhumance Pastoralism in the Deosai Plateau Pakistan. Social, Economic and Ecological Conflicts. Ph.D Thesis, School of Environmental Sciences, Uni. East Anglia, Norwich UK, 113 pp.

Alard, D. and I. Poudevigne. 2000. Diversity patterns in grasslands along a landscape gradient in northwestern France. *J. Veg. Sci.*, 11(2): 287-294.

Ali, S.I. and M. Qaiser. (Eds.). 1993-2007. Flora of Pakistan. No. 191-215. Islamabad, Karachi.

Ali, S.I. and Y.J. Nasir. (Eds.). 1989-1992. Flora of Pakistan. Nos. 191-204. Islamabad, Karachi.

Austrheim, G., Hassel, K., & Mysterud, A. (2005). The role of life history traits for bryophyte community patterns in two contrasting alpine regions. The bryologist, 108(2), 259-271.

Bai, Y., X. Han, J. Wu, Z. Chen and L. Li. 2004. Ecosystem stability and compensatory effects in the Inner Mongolia grassland. *Nature*, 431: 181-184.

Barrera, M.D., J.L. Frangi, L.L. Richter, M.H. Perdomo and L.B. Pinedo. 2000. Structural and functional changes in Nothofagus pumilio forests along an altitudinal gradient in Tierra del Fuego, Argentina. *J. Veg. Sci.*, 11: 179-188.

Borer, E.T., E.W. Seabloom, D.S. Gruner, W.S. Harpole, H. Hillebrand, E.M. Lind and J.D. Bakker. 2014. Herbivores and nutrients control grassland plant diversity via light limitation. *Nature*, 508(7497): 517-520.

Cavaliere, C. 2009. The Effects of Climate Change on Medicinal and Aromatic Plants. *Amr. Bot. Coun.*, 44-57 pp.

Cox, T.F. and T. Lewis. 1976. A conditioned distance ratio method for analyzing spatial patterns. *Biometrika*, 63: 483-491.

Eriksson, O. and B. Bremer. 2001. Fruit characteristics, life forms and species richness in the plant family Rubiaceae. *Am. Nat*., 138: 751-761.

Gibson, D.G., L. Young, R.Y. Chuang, J.C. Venter, C.A. Hutchison and H.O. Smith. 2009. Enzymatic assembly of DNA molecules up to several hundred kilobases. *Nat. Meth*., 6(5): 343-345.

Heaney, A. and J. Proctor. 1989. Chemical elements in fitter at a range of altitude on Volcanbarva, Costa Rica: Nutrients in Tropical Forest and Savanna Ecosystems. Blackwell scientific publications, Oxford. *J. Proctor*, pp. 255-271.

IUCN 2017. *The IUCN Red List of Threatened Species. Version 2017-3*. <http://www.iucnredlist.org>. Downloaded on 05, 12, 2017.

Karan, P.P. 2006. Geographic regions of the Himalayas, Namgyal Institute of the Tibetology, 103-116 pp.

Khan, K.U., M. Shah, H. Ahmad, M. Ashraf. I.U. Rahman, Z. Iqbal, S.M. Khan and A. Majid. 2015. Investigation of Traditional Veterinary Phytomedicines Used in Deosai Plateau. *Pak. G.V*., 15(4): 381-388, 2015 ISSN, 1992-6197.

Khan, S.B., M. Faisal, M.M. Rahman and A. Jamal. 2011. Exploration of CeO2 nanoparticles as a chemi-sensor and photo-catalyst for environmental applications. *Science of the total Environment,* 409(15): 2987-2992.

Khan, W., S.M. Khan, H. Ahmad, A.A. Alqarawi, G.M. Shah, M. Hussain and E. Abd-Allah. 2016. Life forms, leaf size spectra, regeneration capacity and diversity of plant species grown in the Thandiani forests, district Abbottabad, Khyber Pakhtunkhwa, Pakistan. *Saudi J. Bio. Sci.*, http://dx.doi.org/10.1016/j.sjbs.2016.11.009

Korner, C. 2003. Alpine plant life: functional plant ecology of high mountain ecosystems. Springer, Berlin., 338 pp.

Magurran, A. 2005. Species abundance distributions: pattern or process? *Funct. Ecol*., 19(1): 177-181.

Magurran, A.E. 2004. Measuring biological diversity. Blackwell Publishing, Oxford, U. K.

Maikhuri, R., R. Semwal, K. Rao, K. Singh and K. Saxena. 2000. Growth and ecological impacts of traditional agroforestry tree species in Central Himalaya, India. *Agro for. Sys.*, 48(3): 257-271.

Manier, D.J. and N.T. Hobbs. 2006. Large herbivores influence the composition and diversity of shrub-steppe communities in the Rocky Mountains, USA. Oecologia, 146: 641-651.

McCune B, M.J. Mefford. 2005. Multivariate Analysis of Ecological Data (PCORD Version 5.10 Mj-M Software) Gleneden Beach, Oregon: United State of America.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. New York: John Wiley and sons. Inc., p. 547.

Nasir, E. and S.I. Ali. (Eds.). 1970-1979. Flora of West Pakistan. No. 1-131. Islamabad, Karachi

Nasir, E. and S.I. Ali. (Eds.). 1980-1989. Flora of Pakistan. No. 132-190. Islamabad, Karachi.

Nasir, Z.A. and S. Sultan. 2002. Floristic, biological and leaf size spectra of weeds in gram, lentil, mustard and wheat fields of district Chakwal, Pakistan. *Pak. J. Biol. Sci.*, 5(7): 758-762.

Nautiyal, M.C., B.P. Nautiyal and V. Prakash. 2001. Phenology and growth form distribution in an alpine pasture at Tungnath, Garhwal, Himalaya. *Mountain research and Development*, 21(2): 168-174.

Nawaz, M.A. 2007. Status of Brown Bear in Pakistan. Ursus, 18(1): 89-100.

Pak-Met. 2016. Pakistan Meteorological Department: The Normals of climatic data of Azad Jammu & Kashmir. Islamabad, Pakistan.

Panthi, M.P, R.P. Chaudhary and O.R. Vetaas. 2007. Plant species richness and composition in a trans-Himalayan inner valley of Manang district, central Nepal. *Himal. J. Sci.*, 4(6): 57-64.

Peer, T., J.P. Gruber, A. Millingard and F. Hussain. 2007. Phytosociology, structure and diversity of the steppe vegetation in the mountains of Northern Pakistan. *Phytocoenologia*, 37(1): 1-65.

Pyšek, .P, D.M. Richardson, M. Williamson. 2004. Predicting and explaining plant invasions through analysis of source area floras: some critical considerations. *Diversity and Distribution*, 10: 179-187.

Rahman, A., S.M. Khan, A. Hussain, I.U. Rahman, Z. Iqbal and F. Ijaz. 2016. Ecological assessment of plant communities and associated edaphic and topographic variables of the Peochar Valley District Swat of the Hindu Kush Mountains. *Moun. Res. Dev.*, 36(3): 332-341.

Raunkiær, C. 1934. The Life Forms of Plants and Statistical Plant Geography, being the collected papers of C. Raunkiær. Oxford University Press, Oxford. Reprinted 1978 (ed. by Frank N. Egerton), Ayer Co Pub., in the History of Ecology Series, ISBN 0-405-10418-9.

Rawat, G.S. 2007. Pastoral Practices, Wild Mammals and Conservation Status of Alpine Meadows in Western Himalaya. *J. Bombay Nat. Hist. Soc.,* 104 (1): 5-11.

Rawat, G.S. and B.S. Adhikari. 2005. Floristics and distribution of plant communities across moisture and topographic gradients in Tso Kar basin, Changthang plateau, eastern Ladakh. *Arctic, Antarctic, and Alpine Research*, 37(4): 539-544.

Richardson, D.M., P. Pysek, M. Rejmanek, M.G. Barbour, F.D. Panetta and C.J. Wes. 2000. Naturalization and invasion of alien plants concepts and definitions. *Diversity and Distribution,* 6: 93-107.

Salick, J. and A. Byg. 2007. Indigenous peoples and climate change. In Indigenous peoples and climate change. Tyndall Centre Publication.

Samant S.S., U. Dhar and R.S. Rawal. 1998. Biodiversity status of a protected area in West Himalaya: Askot Wildlife Sanctuary. *Int. J. SDW Ecol.,* 5: 194-203.

Shaheen, H. and R.A. Qureshi. 2011. Vegetation types of Sheosar Lake and surrounding landscape in Deosai plains of North Pakistan, Western Himalayas. *J. Mou. Res.,* 5(4): 599-603.

Shankar, V. and R.P. Singh. 1995. Biodiversity of Himalayan Rangelands and its Conservation. Indian Grassland and Fodder Res. *Ins. Jhansi, Ind.,* FAO. Publication, p; 8

Sher, Z. and Z.U. Khan. 2007. Floristic composition, life form and leaf spectra of the vegetation of Chagharzai Valley, District Buner. *Pak. J. Pl. Sci.,* 13(1): 57-66.

Tambe, S. and G.S. Rawat. 2010. The alpine vegetation of the Khangchendzonga landscape, Sikkim Himalaya: community characteristics, diversity, and aspects of ecology. *Mountain Research and Development*, 30(3): 266-274.

Tiessen, H. and R. Wu. 2002. Effect of land use on soil degradation in alpine grassland soil, China. *Soil Sci. Soci. Amr. J.,* 66: 1648-1655.

Weiher, E. and P.A. Keddy. 1999. Relative abundance and evenness patterns along diversity and biomass gradients. Oikos 87: 355-361.

Wesche, K., G. Miehe and M. Kaeppeh. 2000. The significance of fire for afro-alpine vegetation. *Moun. Res. Dev*., 20: 340-347.

Wilsey, B.J., D.R. Chalcraft, C.M. Bowles and M.R. Willig. 2005. Relationships among indices suggest that richness is an incomplete surrogate for grassland biodiversity. *Ecol*., 86(5): 1178-1184.

Yang, Y.H. and S.L. Piao. 2006. Variations in grassland vegetation cover in relation to climatic factors on the Tibetan Plateau. *J. Plant Ecol*., 30: 1-8.

Zhang, X.K., X.Y. Lu and X. Wang. 2015. Spatial-temporal NDVI variation of different alpine grassland classes and groups in northern Tibet. *Mt. Res. Dev*., 35: 254-263.

(Received for publication 31 January 2018)