Biological Forum – An International Journal **12(2): 01-12(2020)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Diversity of Herbs in Kibber Wildlife Sanctuary of Distt. Lahaul and Spiti, Himachal Pradesh

Ranjeet Kumar, Raj Kumar Verma, Suraj Kumar, Chaman Thakur, Rajender Prakash, Krishna Kumari, Dushyant and Saurabh Yadav
Himalayan Forest Research Institute,
Panthaghati, Shimla (Himachal Pradesh), India.

(Corresponding author: Ranjeet Kumar)
(Received 09 June 2020, Accepted 29 July, 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The cold desert in Himalayas are home of unique and threatened plants. The landscapes of cold deserts are rich in biodiversity due to unique topography, climatic conditions and variation in plant diversity in different habitats. The plant diversity provides information on plant wealth of particular area. The present investigation was conducted to know the phytodiversity of herbs in Kibber Beat of Kibber Wildlife Sanctuary (KWLS) during 2017-2019. The study included dominance of vegetation, diversity indices and documentation of threatened plants. Total 12 communities, 22 family, 50 genera and 71 species were recorded during the study in Kibber Beat of the Sanctuary. Total 4 numbers of threatened plants were recorded viz., *Arnebia euchroma, Berginia stracheyi, Physochlaena praealta* and *Rhodiola heterodonta*. Total density/m^2 of herbs varied from 7.35 to 54.85. Maximum value of diversity index (H) in communities was 2.84 and minimum was 1.81. *Ex-situ* conservation of plants is required to conserve the diversity of plants of the cold desert.

Keywords: Cold desert, Kibber, herbs, community and phytosociology.

I. INTRODUCTION

Himalaya is the youngest mountains chain in the world comprises about 10% of the total land surface of India. It shows a great endemism for flora as well fauna. Endowed with a large range of natural variety and floristic composition, it has large number of floral and faunal species including about 9000 species of angiosperms, of which 3470 species considered endemic to Himalaya, thus categorized it as one of the biodiversity hotspot (Verma and Kapoor, 2010).

The cold desert comes under the Trans-Himalayan zone and covers an area of 98,980 km^2. It covers an area of 82,655 km^2 in union territories Ladakh and Jammu & Kashmir, 15000 km^2 in Lahaul-Spiti and Kinnaur in Himachal Pradesh and 1000 km^2 in Nelang valley, Mana and Niti valley (Uttarakhand). The cold deserts in Himachal Pradesh cover nearly 35 per cent of its geographical area (Negi, 1985). The cold deserts are gifted with very distinct characteristics like low precipitation, huge variation in temperature in day and night, sandy and arid soils with low fertility and very less humidity in atmosphere which all together give rise to very diverse flora on earth.

The growing season in the area is short due to its unique climatic condition and summer is only growing period for the plants (Kapoor, 2004). The flora of Indian Cold Desert comes under alpine and high alpine zones. In Western, Himalaya Alpine zone where the trees are almost absent and the flora is dominated by wild annual and perennial herbs followed by dwarf bushes or shrubs (Saxena *et al.*, 2018).

The fascinating flora of Lahaul- Spiti has attracted the attention of many researchers for more knowledge and diversity studies (Negi *et al.*, 2019). The plants of cold desert are experiencing the pressure due to habitat destruction, climate change and over exploitation for economical purposes by local people and other as well. The live stocks and migratory grazers are also responsible for degradation of fragile ecosystem due to overgrazing.

Once biodiversity is lost in any area we cannot regain it through human efforts (Verma *et al.*, 2003). The quantitative assessment of floristic diversity as well as identification and classification of plant communities have been studied by various researchers with objective of conservation and management (Sharma & Samant, 2019; Singh, 2008; Tilman *et al.*, 2001; Bruno *et al.*, 2003; Kikvidze *et al.*, 2005; Khanna & Shukla, 2019; Mallick, 2020 and Rana *et al.*, 2011). A few studies have been conducted on community pattern by various researchers (Gautam *et al.*, 2011; Arya and Samant, 2016; Kaul & Sarin, 1971; Rawat & Pangtey, 1987; Joshi & Srivastava, 1988; Negi, *et al.*, 1992 and Samant *et al.*, 2002, Verma, 2015; Sharma and Mishra 2009; Verma and Kapoor, 2010, 2014; Verma, 2017; Kumar and Duggal, 2019). The conservation of biodiversity is the need of the hour as well as practiced throughout the world since long time. The 16th Biosphere Reserve of India is cold desert including Kibber Wild Life

Sanctuary and Pin Valley National Park (Srivastava, 2010 and Devi *et al.*, 2013). The notification of Kibber Wildlife Sanctuary (KWLS) was done in 1999. There was very less efforts made on evaluation of communities for diversity in the sanctuary which makes this study more helpful for the baseline information for the scientific community and forest department. Keeping these facts in views an attempt has been made to record the herbs diversity of Kibber Wildlife sanctuary.

II. MATERIAL AND METHODS

Study area: Kibber Wildlife Sanctuary (KWLS) is situated in Spiti division of district Lahaul and Spiti in Himachal Pradesh. It lies between 32° 8′ 49.082" to 32° 45′39.903" N latitudes and 77° 47′ 59.726" to 78° 31′ 29.452" E longitudes. The wildlife sanctuary is spreaded over 2220.12 km^2 which is bordered in the northern catchment of the Spiti river and is enclosed by Ladakh in the north and Tibet in the east (Kala, 2005). The sanctuary has three beats i.e. Kibber, Langza and Lalung. The area (Km^2) of Kibber beat is 1124.50 Km^2, respectively. The research work was done in Kibber beat in the Sanctuary. Temperature in the cold desert generally varies from -45°C during winter to 40°C in summers and very less rainfall (below 60 mm). The pH of soil ranges generally from 7.4 to 9.4 (Tewari & Kapoor, 2013). The soil has low fertility status and poor water retention capacity (Kapoor, 2004)

Field sampling and data collection: The sites to carry out the studies were finalized after carrying out thorough survey of Kibber beat in Kibber Wild Life Sanctuary (KWLS). Attempts have been made to select site randomly at altitudinal range between 4200 m to 5000 m amsl. The communities were identified on the basis of Importance Value Index of species. Studies for herbs were carried out by laying out the quadrats randomly along or across the selected altitudinal gradients. Detailed information with reference to floristic and related ecological parameters was recorded for each site (Table 1). Vegetation data was collected using 40 quadrates of 1m × 1m for herbs in all communities except community III where 80 quadrates were laid out at two locations as geocoordinates are mentioned in Table 1.

Table 1: The geo-coordinates and other details of different identified communities of KWLS in Himachal Pradesh.

S. No.	Community Types	Aspect	Slope (°)	Altitude (m)	Latitude (N)	Longitude (E)
1	*Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community	NW	10°-30°	4508	32°21'01.8"	078°02'05.2"
2.	*Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community	NW	25°-35°	4881	32°21'19.8"	078°02'54.6"
3.	*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community	NW	10°-30°	4956	32°18'47.9"	078°03'15.4"
		NW	15°-35°	5025	32°18'55.1"	078°03'13.7"
4.	*Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community	NW	25°-40°	4327	32°22'17.0"	077°00'04.5"
5.	*Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community	NW	25°-35°	4457	32°22'20.9"	078°00'18.1"
6.	*Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community.	NW	20°-35°	4468	32°23'51.2"	077°58'61.2"
7.	*Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community.	NW	30°-35°	4924	32°24'10.2"	078°00'00.4"
8.	*Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community.	NW	5°-25°	4488	32°18'29.6"	078°01'54.7"
9.	*Lindelofia stylosa - Carex* sp.-*Allium carolinianum* mixed community.	NW	25°-40°	4807	32°18'54.7"	078°02'44.8"
10.	*Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community.	NW	25°-35°	4467	32°23'54.1"	077°57'35.2"
11.	*Calamogrostis* sp. -*Berginia stracheyi - Rheum tibeticum* mixed community.	NW	25°-40°	4844	32°18'54.7"	078°02'44.8"
12.	*Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.	NE	10°-35°	4597	32°37'43.5"	078°19'12.3"

III. DATA ANALYSIS

The vegetation was analyzed by calculating the density, frequency, abundance, IVI using the formulas given by Curtis and Macintosh (1950). The relative values of density, frequency and dominance were summed to get Importance Value Index (IVI) of individual species. The abundance to frequency ratio (A/F) of different species was determined for eliciting the distribution pattern. This ratio indicated regular (<0.025), random (0.025 to 0.050) and contiguous (>0.050) distribution (Curtis and Cottam, 1956). The plant species diversity was calculated by using Shanon-Wiener diversity Index (H) (Shannon-Wiener, 1963). Concentration of dominance (C) was measured by Simpson's Index (Simpson, 1949). Richness Index was estimated as per Margalef (1958) *i.e.* R = S-1/ln N whereas Evenness Index was calculated as per Hill (1973) *i.e.* E = H/ ln S, where S= total number of species, N= total number of individuals of all the species, H = Index of diversity.

IV. RESULTS AND DISCUSSION

Total 71 plant species belonging to 50 general and 22 families of herbs were recorded during the study. It also included 4 threatened plants i.e. *Arnebia euchroma, Berginia stracheyi*, *Physochlaena praealta* and *Rhodiola heterodonta*. The status of *Rheum spiciforme* is near threatened (Goraya *et al.*, 2013). Total 12 communities of plants were found during sampling in Kibber beat of Kibber Wildlife Sanctuary (KWLS) and list of name and numbers of communities are mentioned in Table 1.

(i) *Elymus nutans*- *Allium carolinianum*- *Lindelofia stylosa* mixed community

Phytosociological analysis of herbs (Table 2) at community-I showed that total number of species of herbs was 16. *Elymus nutans* showed highest value for density/m^2 (2.80) followed by *Allium carolinianum* (0.70), *Leontopodium himalayanum* (0.45), *Lindelofia stylosa* (0.38) and lowest value (0.10) was observed for *Arabidopsis himalaica* (Table 2). Maximum frequency % was observed for *Allium carolinianum* (15.00) followed by *Elymus nutans* (12.50), *Corydalis thyrsiflora* (10.00) and *Cousinia thomsonii* (10.00) and minimum value (5.00) was observed for *Arabidopsis himalaica, Polygonum cognatum* and *Potentilla bifurca* (Table 3). Maximum abundance was observed for *Elymus nutans* (22.40) followed by *Leontopodium himalayanum* (5.45), *Allium carolinianum* (4.67) and minimum value (2.00) was observed for *Arabidopsis himalaica* (Table 4). *Elymus nutans* (61.64) was dominant species on the basis of IVI followed by *Allium carolinianum* (49.73), *Lindelofia stylosa* (34.60) and least dominant was *Arabidopsis himalaica* (6.14) (Table 5).

(ii) *Elymus nutans* - *Stipa capillata* - *Berginia stracheyi* mixed community

A perusal of Table 2 for herbs at community-II showed that total number of herbs species was 11. *Elymus nutans* showed highest value for density/m^2 (15.85) followed by *Stipa capillata* (8.63), *Bergenia stracheyi* and *Corydalis thyrsiflora* (0.45) and lowest value (0.08) was observed for *Aconitum* sp. (Table 2). Maximum frequency % (Table 3) was observed for *Elymus nutans* (20.00) followed by *Bergenia stracheyi* (15.00), *Stipa capillata* (12.50) and minimum value (5.00) was observed for *Aconitum* sp., *Rheum tibeticum* and *Saussurea nana*. Maximum abundance was observed for *Elymus nutans* (79.25) followed by *Stipa capillata* (69.00), *Corydalis thyrsiflora* (6.00) and minimum value (1.50) was observed for *Aconitum* sp. (Table 4). *Elymus nutans* (102.00) was dominant species (Table 5) on the basis of IVI followed by *Stipa capillata* (72.91), *Bergenia stracheyi* (42.80) and least dominant was *Aconitum* sp. (5.29).

(iii) *Elymus nutans* - *Stipa* sp.- *Carex* sp. mixed community

A perusal of Table 2 for herbs showed that total number of herbs species was 32. *Elymus nutans* showed highest value for density/m^2 (13.20) followed by *Stipa* sp. (3.36), *Carex* sp. (2.41) and lowest value (0.05) was observed for *Saussurea glacialis*. Maximum frequency % (Table 3) was observed for *Elymus nutans* (20.00) followed *Carex* sp. (10.00), *Elsholtzia eriostachya* (12.50), and minimum value (2.50) was observed for *Aconitum* sp., Maximum abundance (Table 4) was observed for *Elymus nutans* (66.00) followed by *Stipa* sp.. (44.83), *Carex* sp. (19.30) and minimum value (1.33) was observed for *Saussurea glacialis*. *Elymus nutans* (80.31) was dominant species (Table 5) on the basis of IVI followed by *Stipa* sp. (42.03), *Carex* sp. (22.94) and least dominant was *Aconitum sp.* (1.57).

(iv) *Elymus nutans* - *Allium carolinianum* - *Arnebia euchroma* - *Berginia stracheyi* mixed community

Phytosociological analysis of herbs (Table 2) showed that total number of species of herbs was 15. *Elymus nutans* showed highest value for density/m^2 (3.15) followed by *Berginia stracheyi* (0.70) and lowest value (0.13) was observed for *Aconitum* sp. and *Geranium himalayense* (Table 2). Maximum frequency % (Table 3) was observed for *Elymus nutans* (25.00) followed by *Aconogonum tortuosum* (15.00) and minimum value (5.00) was observed for *Aconitum* sp., *Bistoria affinis, Gentiana tianschanica* and *Geranium himalayense*. Maximum abundance (Table 4) was observed for *Bistorta affinis* (13.00) followed by *Elymus nutans* (12.60), and minimum value (2.33) was observed for *Lindelofia stylosa*. *Elymus nutans* (55.42) was dominant species (Table 5) on the basis of IVI followed by *Arnebia euchroma* (29.60), *Berginia stracheyi* (28.32) and least dominant was *Aconitum* sp. (4.61).

Table 2: Density (Ind./m^2) of species within different identified communities of KWLS in Himachal Pradesh.

S. No.	Plant Species	Community Types											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	*Aconitum* sp.		0.08	0.06	0.13				0.08	0.08			
2	*Aconogonum tortuosum* (D. Don) H. Hara			0.11	0.63		0.45		0.25				
3	*Allium carolinianum* DC.	0.7	0.3	0.14	0.65	0.43	4.23		0.38	2.4	6.8		
4	*Alyssum desertorum* Stapf												0.58
5.	*Androsace delavayi* Franch.											1.13	
6.	*Arabidopsis himalaica* (Edgew.) O. E. Schulz	0.1											
7.	*Arnebia euchroma* (Royle *ex* Benth.) I. M. Johnston			0.10	0.65	0.23	0.9		0.13		4.28		
8.	*Artemisia gmelinii Weber ex Stechm.*			0.15					0.23				
9.	*Artemisia salsoloides* Willd.										0.28		
10.	*Artemisia* sp.				0.4								
11.	*Askellia flexuosa* (Ledeb.) W. A. Weber												0.83
12.	*Aster flaccidus* Bunge						0.4	0.65					
13.	*Astragalus* sp.								0.73	0.15			
14.	*Astragalus rhizanthus* Benth.	0.3		0.08		0.15	0.98	0.05	0.15	2.55	1.55		
15.	*Berginia stracheyi* (Hook.f. & Thomson) Engl.		0.45	0.54	0.7	0.53	0.4	1.23	0.4	0.2	3.13	1.05	
16.	*Biebersteinia odora* Stephan ex Fisch.					0.15							

17..	*Bistorta affinis* (D.Don) Greene				0.65								
18.	*Calamogrostis* sp.											40	
19.	*Carex* sp.			2.41		0.53			2.95	5.05			
20.	*Christolea crassifolia* Cambess.			0.24	0.38								1.3
21.	*Christolea himalayensis* (Cambess.) Jafri											0.05	
22.	*Corydalis crassifolia* Royle				0.45			0.3	0.58				
23.	*Corydalis thyrsiflora* Prain	0.4	0.45	0.21									
24.	*Cousinia thomsonii* C. B. Clarke	0.33		0.20			1.18		0.3		0.1		
25.	*Dracocephalum heterophyllum* Benth.			0.14			0.9		0.35				
26.	*Elsholtzia eriostachya (*Benth.*)* Benth.			0.56									
27.	*Elymus nutans* Griseb.	2.8	15.85	13.20	3.15	3.13	11.85	8.95	8.63			6.13	6.18
28.	*Erigeron poncinsii* (Franch.) Botsch.			0.10							1.38		
29.	*Eritrichium canum* (Benth.) Kitam.	0.33				0.5							
30.	*Gagea lutea* (L.) Ker Gawl.											0.23	
31.	*Gentiana moorcroftiana* (Wall. ex Griseb.) Airy Shaw			0.18									
32.	*Gentiana tianschanica* Rupr. ex Kusn.				0.18	0.13				0.2			
33.	*Geranium himalayense* Klotzsch			0.16	0.13		0.23	0.05	0.18	0.78			
34.	*Geranium lambertii* Sweet					0.15							
35.	*Heracleum pinnatum* C.B. Clarke						0.55	0.45			0.5		
36.	*Kobresia royleana* (Nees) Boeckeler										3.13		
37.	*Leontopodium himalayanum* DC.	0.45											
38.	*Lindelofia stylosa* (Kar. & Kir.) Brand	0.38		0.10	0.35	0.23	0.58		1.4	5.25	1.48		
39.	*Myosotis alpestris* F. W. Schmidt			0.29									
40.	*Nepeta eriostachya* Benth.			0.26							1.13		
41.	*Nepeta podostachys* Benth.			0.29					0.43	2			
42.	*Nepeta* sp.				0.43		0.7						
43.	*Oxytropis microphylla* (Pall.) DC.												1.18
44.	*Oxytropis mollis* Benth.	0.3	0.13	0.08									
45.	*Paraquilegia microphylla* (Royle) J.R Drumm. & Hutch.					0.65					0.33	0.7	
46.	*Physochlaina praealta* (Walp.) Miers.												0.3
47.	*Plantago depressa* Willd.			0.08		0.15							
48.	*Plantago* sp.									0.38			
49.	*Polygonum cognatum* Meisn.	0.23											
50.	*Potentilla argyrophylla* Wall. ex Lehm.		0.23	0.30					0.53	0.23		1.03	
51.	*Potentilla bifurca* Linn.	0.15							0.35		2.05		
52.	*Potentilla desertorum* Bunge										0.1		
53.	*Potentilla nivea* Linn.					0.2							
54.	*Potentilla* sp.	0.2			0.65	0.13	0.33	1.23			0.23		
55.	*Rheum spiciforme* Royle		0.15	0.20		0.35	0.15	0.15		0.23		0.15	
56.	*Rheum tibeticum* Maxim. ex Hook. f.		0.1									4	
57.	*Rhodiola crenulata* (Hook. f. Thomson) & Ohba										1.6		
58.	*Rhodiola heterodonta* (Hook. f. & Th.) Boriss			0.24		0.38				0.3	0.63	0.38	
59.	*Rhodiola tibetica* (Hook.f. & Thompson) S. H. Fu						1.15	3.9		0.6	9.78		
60.	*Rhodiola wallichiana* (Hook.) S.H. Fu										1.2		
61.	*Rosularia alpestris* (Kar. & Kir.) Boriss.					0.28							
62.	*Saussurea glacialis Herder.*			0.05				0.1					
63.	*Saussurea nana* (Pamp.) Pamp.		0.15	0.08						0.18			
64.	*Stipa capillata* Linn.		8.63										
65.	*Stipa* sp.			3.36					1.18				
66.	*Tanacetum nubigenum* Wall. ex DC.												1.78
67.	*Taraxacum officinale* Wigg.	0.15		0.16					0.2				
68.	*Thalictrum cultratum* Wall.	0.3		0.33			0.2						
69.	*Thalictrum foetidum* Linn.	0.23							0.33				
70.	*Thermopsis inflata* Cambess.			0.35		0.45	0.4		0.48				
71.	*Thymus linearis* Benth.					0.1							
	Total	**7.35**	**26.52**	**24.72**	**9.53**	**8.85**	**25.58**	**17.06**	**20.24**	**20.58**	**39.68**	**54.85**	**12.15**

Abbreviation used: I = *Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community, II= *Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community, III=*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community, IV= *Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community, V= *Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community, VI= *Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community, VII= *Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community, VIII= *Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community, IX= *Lindelofia stylosa - Carex* sp.- *Allium carolinianum* mixed community, X= *Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community, XI= *Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community and XII= *Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.

(v) *Elymus nutans* - *Allium carolinianum* - *Rheum spiciforme* mixed community

A perusal of Table 2 showed that total number of herbs species was 20. *Elymus nutans* showed highest value for density/m^2 (3.13) followed by *Paraquilegia microphylla* (0.65), *Berginia stracheyi* and *Carex* sp. (0.53) and lowest value (0.10) was observed for *Thymus linearis* (Table 2). Maximum frequency % was observed (20.00) for *Allium carolinianum* and *Elymus nutans* followed by *Berginia stracheyi* (17.50) and minimum value (5.00) was observed for *Biebersteinia odora, Carex* sp., *Gentiana tianschanica, Geranium lambertii, Plantago depressa, Potentilla* sp. *Thermopsis inflate* and *Thymus linearis* (Table 3). Maximum abundance was observed for *Elymus nutans* (15.63) followed by *Carex* sp. (10.50) and minimum value (2.00) was observed for *Astragalus rhizanthus* and *Thymus linearis* (Table 4). *Elymus nutans* (57.66) was dominant species (Table 5) on the basis of IVI followed by *Allium carolinianum* (37.70) and least dominant was *Thymus linearis* (4.41).

Table 3: Frequency percent of species within different identified communities of KWLS in Himachal Pradesh.

S.No.	Plant species	Community Types											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	*Aconitum* sp.		5	2.50	5				2.5	2.5			
2.	*Aconogonum tortuosum* (D. Don) H. Hara			2.50	15		7.5		5				
3.	*Allium carolinianum* DC.	15	10	3.75	12.5	20	50		12.5	20	40		
4.	*Alyssum desertorum* Stapf												15
5.	*Androsace delavayi* Franch.											15	
6.	*Arabidopsis himalaica* (Edgew.) O. E. Schulz	5											
7.	*Arnebia euchroma* (Royle *ex* Benth.) I. M. Johnston			5.00	10	7.5	12.5		2.5		30		
8.	*Artemisia gmelinii Weber ex Stechm.*			5.00					5				
9.	*Artemisia salsoloides* Willd.										7.5		
10.	*Artemisia* sp.				10								
11.	*Askellia flexuosa* (Ledeb.) W. A. Weber												12.5
12.	*Aster flaccidus* Bunge						7.5	17.5					
13.	*Astragalus* sp.								5	2.5			
14.	*Astragalus rhizanthus* Benth.	7.5		3.75		7.5	12.5	5	10	12.5	17.5		
15.	*Berginia stracheyi* (Hook.f.&Thomson) Engl.		15	11.25	10	17.5	7.5	17.5	7.5	5	20	12.5	
16.	*Biebersteinia odora* Stephan ex Fisch.					5							
17.	*Bistorta affinis* (D.Don) Greene				5								
18.	*Calamogrostis* sp.											30	
19.	*Carex* sp.			12.50		5			12.5	30			
20.	*Christolea crassifolia* Cambess.			7.50	7.5								20
21.	*Christolea himalayensis* (Cambess.) Jafri											2.5	
22.	*Corydalis crassifolia* Royle				7.5			5	7.5				
23.	*Corydalis thyrsiflora* Prain	10	7.5	5.00									
24.	*Cousinia thomsonii* C. B. Clarke	10		8.75			50		7.5		5		
25.	*Dracocephalum heterophyllum* Benth.			2.50			10		7.5				
26.	*Elsholtzia eriostachya (*Benth.) Benth.			11.25									
27.	*Elymus nutans* Griseb.	12.5	20	20.00	25	20	37.5	20	12.5			20	30
28.	*Erigeron poncinsii* (Franch.) Botsch.			5.00							12.5		
29.	*Eritrichium canum* (Benth.) Kitam.	7.5				10							
30.	*Gagea lutea* (L.) Ker Gawl.											7.5	
31.	*Gentiana moorcroftiana* (Wall. ex Griseb.) Airy Shaw			7.50									
32.	*Gentiana tianschanica* Rupr. ex Kusn.				5	5				5			
33.	*Geranium himalayense* Klotzsch			8.75	5		7.5	2.5	7.5	12.5			
34.	*Geranium lambertii* Sweet					5							
35.	*Heracleum pinnatum* C.B. Clarke						10	12.5			5		
36.	*Kobresia royleana* (Nees) Boeckeler										7.5		
37.	*Leontopodium himalayanum* DC.	8.25											
38.	*Lindelofia stylosa* (Kar. & Kir.) Brand	15		5.00	15	7.5	7.5		22.5	45	7.5		
39.	*Myosotis alpestris* F. W. Schmidt			5.00									
40.	*Nepeta eriostachya* Benth.			2.50							2.5		
41.	*Nepeta podostachys* Benth.			5.00					15	27.5			
42.	*Nepeta* sp.				12.5		7.5						
43.	*Oxytropis microphylla* (Pall.) DC.												20
44.	*Oxytropis mollis* Benth.	7.5	7.5	3.75									
45.	*Paraquilegia microphylla* (Royle) J.R Drumm. & Hutch.					7.5					5	10	
46.	*Physochlaina praealta* (Walp.) Miers.												2.5
47.	*Plantago depressa* Willd.			5.00		5							
48.	*Plantago* sp.									7.5			
49.	*Polygonum cognatum* Meisn.	5											
50.	*Potentilla argyrophylla* Wall. ex Lehm.		7.5	8.75					7.5	5		12.5	
51.	*Potentilla bifurca* Linn.	5							12.5		30		
52.	*Potentilla desertorum* Bunge										5		
53.	*Potentilla nivea* Linn.					7.5							
54.	*Potentilla* sp.	7.5			10	5	5	17.5			7.5		
55.	*Rheum spiciforme* Royle		7.5	8.75		10	7.5	10		5		7.5	
56.	*Rheum tibeticum* Maxim. ex Hook. f.		5									15	
57.	*Rhodiola crenulata* (Hook. f. Thomson) & Ohba										27.5		

58.	*Rhodiola heterodonta* (Hook. f. & Th.) Boriss			7.50		7.5				2.5	5	10	
59.	*Rhodiola tibetica* (Hook.f. & Thompson) S. H. Fu						7.5	12.5		12.5	22.5		
60.	*Rhodiola wallichiana* (Hook.) S.H. Fu										2.5		
61.	*Rosularia alpestris* (Kar. & Kir.) Boriss.					7.5							
62.	*Saussurea glacialis Herder.*			3.75				5					
63.	*Saussurea nana* (Pamp.) Pamp.		5	3.75						5			
64.	*Stipa capillata* Linn.		12.5										
65.	*Stipa* sp.			7.50					5				
66.	*Tanacetum nubigenum* Wall. ex DC.												35
67.	*Taraxacum officinale* Wigg.	7.5		7.50					7.5				
68.	*Thalictrum cultratum* Wall.	7.5		2.50			7.5						
69.	*Thalictrum foetidum* Linn.	7.5							7.5				
70.	*Thermopsis inflata* Cambess.			3.75		5	5		7.5				
71.	*Thymus linearis* Benth.					5							

Abbreviation used: I= *Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community, II= *Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community, III=*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community, IV= *Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community, V= *Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community, VI= *Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community, VII= *Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community, VIII= *Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community, IX= *Lindelofia stylosa - Carex* sp.- *Allium carolinianum* mixed community, X= *Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community, XI= *Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community and XII= *Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.

(vi) *Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community

Phytosociological analysis of herbs (Table 2) showed that total number of species of herbs was 18. *Elymus nutans* showed highest value for density/m^2 (11.85) followed by *Allium carolinianum* (4.23), *Cousinia thomsonii* (1.18) and lowest value (0.15) was observed for *Rheum spiciforme* (Table 2). Maximum frequency % was observed for *Allium carolinianum* and *Cousinia thomsonii* (50.00) followed by *Elymus nutans* (37.50) and minimum value (5.00) was observed for *Potentilla* sp. and *Thermopsis inflate* (Table 3). Maximum abundance was observed for *Elymus nutans* (31.60) followed by *Rhodiola tibetica* (15.33), *Nepeta* sp. (9.33) and minimum value (2.00) was observed for *Rheum spiciforme* (Table 4). *Allium carolinianum* (69.44) was dominant species (Table 5) on the basis of IVI followed by *Elymus nutans* (65.55), *Cousinia thomsonii* (53.43) respectively and least dominant was *Thalictrum cultratum* (3.95).

(vii) *Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community

A perusal of Table 2 showed that total number of herbs species was 11. *Elymus nutans* showed highest value for density/m^2 (8.95) followed by *Rhodiola tibetica* (3.90), *Berginia stracheyi* and *Potentilla* sp. (1.23) and lowest value (0.05) was observed for *Astragalus rhizanthus* and *Geranium himalayense* (Table 2). Maximum frequency % was observed for *Elymus nutans* (20.00) followed by *Aster flaccidus, Berginia stracheyi* and *Potentilla* sp. (17.50) and minimum value (2.50) were observed for *Geranium himalayense* (Table 3). Maximum abundance was observed for *Elymus nutans* (44.75) followed by *Rhodiola tibetica* (31.20), *Potentilla* sp. (7.00) and minimum value (1.00) was observed for *Astragalus rhizanthus* (Table 4). *Elymus nutans* (116.00) was dominant species (Table 5) on the basis of IVI followed by *Rhodiola tibetica* (59.72) and least dominant was *Geranium himalayense* (2.44).

(viii) *Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community

A perusal of Table 2 showed that total number of herbs species was 22. *Elymus nutans* showed highest value for density/ m^2 (8.63) followed by *Carex* sp. (2.95) and lowest value (0.08) was observed for *Aconitum* sp. (Table 2). Maximum frequency % (Table 3) was observed for *Lindelofia stylosa* (22.50) followed by *Nepeta podostachys* (15.00) and minimum value was observed for was *Aconitum* sp. and *Arnebia euchroma* (2.50). Maximum abundance was observed for *Elymus nutans* (69.00) followed by *Carex* sp. (23.60), *Stipa* sp. (23.50) and minimum value (1.50) was observed for *Astragalus rhizanthus* (Table 4). *Lindelofia stylosa* (56.42) was dominant species (Table 5) on the basis of IVI followed by *Elymus nutans* (55.90), *Carex* sp. (39.47) and least dominant was *Aconitum* sp. (1.77).

(ix) *Lindelofia stylosa - Carex* sp. *-Allium carolinianum* mixed community

A perusal of Table 2 for herbs showed that total number of herb species was 16. *Lindelofia stylosa* showed highest value for density/m^2 (5.25) followed by *Carex* sp. (5.05) and lowest value (0.08) was observed for *Aconitum* sp (Table 2). Maximum frequency % was observed for *Lindelofia stylosa* (45.00) followed by *Carex* sp. (30.00) and minimum value (2.50) was observed for *Aconitum* sp., *Astragalus* sp. *Rhodiola heterodonta* (Table 3). Maximum abundance was observed for *Astragalus rhizanthus* (20.40) followed by *Carex* sp. (16.83) and minimum value (3.00) was observed for *Aconitum* sp. (Table 4). *Lindelofia stylosa* (70.22) was dominant species on the basis of IVI (Table 5) followed by *Carex* sp. (65.00) and least dominant was *Aconitum* sp. (1.71).

(x) *Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community

A perusal of Table 2 showed that total number of species of herbs was 19. *Rhodiola tibetica* showed highest value for density/m^2 (9.78) followed by *Allium carolinianum* (6.80) and lowest value (0.10) was observed for *Potentilla desertorum* (Table 2). Maximum frequency % was observed for *Allium carolinianum* (40.00) followed by *Arnebia euchroma* (30.00), *Potentilla bifurca* (30.00), *Rhodiola crenulata* (27.50) and minimum value (2.50) were observed for *Nepeta eriostachya* and *Rhodiola wallichiana* (Table 3). Maximum abundance (Table 4) was observed for *Rhodiola wallichiana* (48.00) followed by *Nepeta eriostachya* (45.00), *Rhodiola tibetica* (43.44) and minimum (2.00) was *Cousinia thomsonii* and *Potentilla desertorum*. *Bergenia stracheyii* (81.88) was dominant species (Table 5) on the basis of IVI followed by *Allium carolinianum* (37.48), *Rhodiola tibetica* (37.50) and least dominant was *Potentilla desertorum* (2.31).

Table 4. Abundance of species within different identified communities of KWLS in Himachal Pradesh.

S. No.	Plant species	Community Types											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	*Aconitum* sp.		1.5	2.50	2.5				3	3			
2.	*Aconogonum tortuosum* (D. Don) H. Hara			4.50	4.17		6		5				
3.	*Allium carolinianum* DC.	4.67	3	3.67	5.2	2.13	8.45		3	12	17		
4.	*Alyssum desertorum* Stapf												3.83
5.	*Androsace delavayi* Franch.											7.5	
6.	*Arabidopsis himalaica* (Edgew.) O. E. Schulz	2											
7.	*Arnebia euchroma* (Royle *ex* Benth.) I. M. Johnston			2.00	6.5	3	7.2		5		14.25		
8.	*Artemisia gmelinii Weber ex Stechm.*			3.00					4.5				
9.	*Artemisia salsoloides* Willd.										3.67		
10.	*Artemisia* sp.				4								
11.	*Askellia flexuosa* (Ledeb.) W. A. Weber												6.6
12.	*Aster flaccidus* Bunge						5.33	3.71					
13.	*Astragalus* sp.								14.5	6			
14.	*Astragalus rhizanthus* Benth.	4		2.00		2	7.8	1	1.5	20.4	8.86		
15.	*Berginia stracheyi* (Hook.f. & Thomson) Engl.		3	4.78	7	3	5.33	7	5.33	4	15.63	8.4	
16.	*Biebersteinia odora* Stephan ex Fisch.					3							
17.	*Bistorta affinis* (D.Don) Greene				13								
18.	*Calamogrostis* sp.											133.3	
19.	*Carex* sp.			19.30		10.5			23.6	16.83			
20.	*Christolea crassifolia* Cambess.			3.17	5								6.5
21.	*Christolea himalayensis* (Cambess.) Jafri											2	
22.	*Corydalis crassifolia* Royle				6			6	7.67				
23.	*Corydalis thyrsiflora* Prain	4	6	4.25									
24.	*Cousinia thomsonii* C. B. Clarke	3.25		2.29			2.35		4		2		
25.	*Dracocephalum heterophyllum* Benth.			5.50			9		4.67				
26.	*Elsholtzia eriostachya (*Benth.*)* Benth.			5.00									
27.	*Elymus nutans* Griseb.	22.4	79.25	66.00	12.6	15.63	31.6	44.75	69			30.63	20.58
28.	*Erigeron poncinsii* (Franch.) Botsch.			2.00							11		
29.	*Eritrichium canum* (Benth.) Kitam.	4.33				5							
30.	*Gagea lutea* (L.) Ker Gawl.											3	
31.	*Gentiana moorcroftiana* (Wall. ex Griseb.) Airy Shaw			2.33									
32.	*Gentiana tianschanica* Rupr. ex Kusn.				3.5	2.5				4			
33.	*Geranium himalayense* Klotzsch			1.86	2.5		3	2	2.33	6.2			
34.	*Geranium lambertii* Sweet					3							
35.	*Heracleum pinnatum* C.B. Clarke						5.5	3.6			10		
36.	*Kobresia royleana* (Nees) Boeckeler										41.67		
37.	*Leontopodium himalayanum* DC.	5.45											
38.	*Lindelofia stylosa* (Kar. & Kir.) Brand	2.5		2.00	2.33	3	7.67		6.22	11.67	19.67		
39.	*Myosotis alpestris* F. W. Schmidt			5.75									
40.	*Nepeta eriostachya* Benth.			10.50							45		
41.	*Nepeta podostachys* Benth.			5.75					2.83	7.27			
42.	*Nepeta* sp.				3.4		9.33						
43.	*Oxytropis microphylla* (Pall.) DC.												5.88
44.	*Oxytropis mollis* Benth.	4	1.67	2.00									
45.	*Paraquilegia microphylla* (Royle) J.R Drumm. & Hutch.					8.67					6.5	7	
46.	*Physochlaina praealta* (Walp.) Miers.												12
47.	*Plantago depressa* Willd.			1.50		3							
48.	*Plantago* sp.									5			
49.	*Polygonum cognatum* Meisn.	4.5											
50.	*Potentilla argyrophylla* Wall. ex Lehm.		3	3.43					7	4.5		8.2	
51.	*Potentilla bifurca* Linn.	3							2.8		6.83		
52.	*Potentilla desertorum* Bunge										2		
53.	*Potentilla nivea* Linn.					2.67							
54.	*Potentilla* sp.	2.67			6.5	2.5	6.5	7			3		
55.	*Rheum spiciforme* Royle		2	2.29		3.5	2	1.5		4.5		2	
56.	*Rheum tibeticum* Maxim. ex Hook. f.		2									26.67	
57.	*Rhodiola crenulata* (Hook. f. Thomson) & Ohba										5.82		
58.	*Rhodiola heterodonta* (Hook. f. & Th.) Boriss			3.17		5				12	12.5	3.75	
59.	*Rhodiola tibetica* (Hook.f. & Thompson) S. H. Fu						15.33	31.2		4.8	43.44		
60.	*Rhodiola wallichiana* (Hook.) S.H. Fu										48		
61.	*Rosularia alpestris* (Kar. & Kir.) Boriss.					3.67							
62.	*Saussurea glacialis Herder.*			1.33				2					
63.	*Saussurea nana* (Pamp.) Pamp.		3	2.00						3.5			
64.	*Stipa capillata* Linn.		69										
65.	*Stipa* sp.			44.83					23.5				
66.	*Tanacetum nubigenum* Wall. ex DC.												5.07
67.	*Taraxacum officinale* Wigg.	2		2.17					2.67				
68.	*Thalictrum cultratum* Wall.	4		13.00			2.67						
69.	*Thalictrum foetidum* Linn.	3							4.33				
70.	*Thermopsis inflata* Cambess.			9.33		9	8		6.33				
71.	*Thymus linearis* Benth.					2							

Abbreviation used: I= *Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community, II= *Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community, III=*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community, IV= *Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community, V= *Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community, VI= *Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community, VII= *Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community, VIII= *Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community, IX= *Lindelofia stylosa - Carex* sp.- *Allium carolinianum* mixed community, X= *Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community, XI= *Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community and XII= *Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.

Table 5: Importance Value Index (IVI) of species within different identified communities of KWLS in Himachal Pradesh.

S. No.	Plant Species	Community Types											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	*Aconitum* sp.		5.29	1.57	4.61				1.77	1.71			
2.	*Aconogonum tortuosum* (D. Don) H. Hara			1.96	17.4		5.29		4.12				
3.	*Allium carolinianum* DC.	49.7	17.4	5.12	35.2	37.7	69.4		10.8	31.8	37.5		
4.	*Alyssum desertorum* Stapf												31.9
5.	*Androsace delavayi* Franch.											13.7	
6.	*Arabidopsis himalaica* (Edgew.) O. E. Schulz	6.14											
7.	*Arnebia euchroma* (Royle *ex* Benth.) I. M. Johnston			7.11	29.6	8.36	14.3		2.47		26.7		
8.	*Artemisia gmelinii Weber ex Stechm.*			5.97					3.9				
9.	*Artemisia salsoloides* Willd.										3.94		
10.	*Artemisia* sp.				11.1								
11.	*Askellia flexuosa* (Ledeb.) W. A. Weber												26.9
12.	*Aster flaccidus* Bunge						5.21	21.5					
13.	*Astragalus* sp.								7.35	3.16			
14.	*Astragalus rhizanthus* Benth.	13.3		2.40		12.7	11.6	4.7	6.05	22.1	11.7		
15.	*Berginia stracheyi* (Hook.f.&Thomson) Engl.		42.8	9.85	28.3	19.5	7.1	35	11.5	6.27	81.9	48.3	
16.	*Biebersteinia odora* Stephan ex Fisch.					5.57							
17.	*Bistorta affinis* (D.Don) Greene				24.6								
18.	*Calamogrostis* sp.											116	
19.	*Carex* sp.			22.94		10.7			39.5	65			
20.	*Christolea crassifolia* Cambess.			5.84	13.1								44
21.	*Christolea himalayensis* (Cambess.) Jafri											1.97	
22.	*Corydalis crassifolia* Royle				12.5			6.74	8.38				
23.	*Corydalis thyrsiflora* Prain	14.3	9.86	3.84									
24.	*Cousinia thomsonii* C. B. Clarke	32.1		9.94			53.4		10.1		2.61		
25.	*Dracocephalum heterophyllum* Benth.			4.50			9.08		5.92				
26.	*Elsholtzia eriostachya (*Benth.*)* Benth.			8.97									
27.	*Elymus nutans* Griseb.	61.6	102	80.31	55.4	57.7	65.5	116	55.9			27.1	87.2
28.	*Erigeron poncinsii* (Franch.) Botsch.			5.81							10.8		
29.	*Eritrichium canum* (Benth.) Kitam.	11.8				14.3							
30.	*Gagea lutea* (L.) Ker Gawl.											5.9	
31.	*Gentiana moorcroftiana* (Wall. ex Griseb.) Airy Shaw			4.86									
32.	*Gentiana tianschanica* Rupr. ex Kusn.				11.8	5.95				4.17			
33.	*Geranium himalayense* Klotzsch			5.31	4.79		3.96	2.44	4.96	12.2			
34.	*Geranium lambertii* Sweet					5.14							
35.	*Heracleum pinnatum* C.B. Clarke						7.05	13.1			3.48		
36.	*Kobresia royleana* (Nees) Boeckeler										13		
37.	*Leontopodium himalayanum* DC.	13.8											
38.	*Lindelofia stylosa* (Kar. & Kir.) Brand	34.6		3.41	23.6	16.4	9.72		56.4	70.2	17.6		
39.	*Myosotis alpestris* F. W. Schmidt			4.52									
40.	*Nepeta eriostachya* Benth.			3.01							4.08		
41.	*Nepeta podostachys* Benth.			4.23					14.9	26.4			
42.	*Nepeta* sp.				13.4		6.84						
43.	*Oxytropis microphylla* (Pall.) DC.												29
44.	*Oxytropis mollis* Benth.	11.1	8.51	2.62									
45.	*Paraquilegia microphylla* (Royle) J.R Drumm. & Hutch.					14					2.81	8.51	
46.	*Physochlaina praealta* (Walp.) Miers.												15.2
47.	*Plantago depressa* Willd.			3.06		6.55							

48.	*Plantago* sp.									6.88			
49.	*Polygonum cognatum* Meisn.	7.68											
50.	*Potentilla argyrophylla* Wall. ex Lehm.		9.53	6.33					12.3	4.38		11	
51.	*Potentilla bifurca* Linn.	6.23							10.5		17		
52.	*Potentilla desertorum* Bunge										2.31		
53.	*Potentilla nivea* Linn.					8.37							
54.	*Potentilla* sp.	8.85			14.6	4.74	4.5	22.4			3.5		
55.	*Rheum spiciforme* Royle		12.3	13.67		26.4	7.74	11.6		6.74		9.57	
56.	*Rheum tibeticum* Maxim. ex Hook. f.		5.58									39	
57.	*Rhodiola crenulata* (Hook. f. Thomson) & Ohba										15.8		
58.	*Rhodiola heterodonta* (Hook. f. & Th.) Boriss			9.85		23.9				9.26	4.03	19.2	
59.	*Rhodiola tibetica* (Hook.f. & Thompson) S. H. Fu						10.2	59.7		24.4	36.6		
60.	*Rhodiola wallichiana* (Hook.) S.H. Fu										4.93		
61.	*Rosularia alpestris* (Kar. & Kir.) Boriss.					9.24							
62.	*Saussurea glacialis Herder.*			2.34				7.17					
63.	*Saussurea nana* (Pamp.) Pamp.		13.5	5.80						5.22			
64.	*Stipa capillata* Linn.		72.9										
65.	*Stipa* sp.			42.03					11.7				
66.	*Tanacetum nubigenum* Wall. ex DC.												65.8
67.	*Taraxacum officinale* Wigg.	9.04		4.75					7.14				
68.	*Thalictrum cultratum* Wall.	10.4		3.33			3.95						
69.	*Thalictrum foetidum* Linn.	9.35							5.61				
70.	*Thermopsis inflata* Cambess.			4.76		8.58	5.1		8.77				
71.	*Thymus linearis* Benth.					4.41							
	Total	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**

Abbreviation used: I= *Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community, II= *Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community, III=*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community, IV= *Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community, V= *Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community, VI= *Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community, VII= *Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community, VIII= *Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community, IX= *Lindelofia stylosa - Carex* sp.- *Allium carolinianum* mixed community, X= *Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community, XI= *Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community and XII= *Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.

Table 6: Concentration of dominance (C), diversity index (H), richness index (R) and evenness index (E)of different identified communities of KWLS in Himachal Pradesh.

S.No.	Communities	Concentration of Dominance (C)	Diversity Index (H)	Richness Index (R)	Evenness Index (E)
1.	*Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community	0.11	2.47	2.64	0.89
2.	*Elymus nutans - Stipa capillata - Berginia stracheyi* mixed community	0.21	1.89	1.44	0.79
3.	*Elymus nutans - Stipa* sp.- *Carex* sp. mixed community	0.11	2.84	4.08	0.82
4.	*Elymus nutans - Allium carolinianum - Arnebia euchroma - Berginia stracheyi* mixed community	0.09	2.52	2.36	0.93
5.	*Elymus nutans - Allium carolinianum - Rheum spiciforme* mixed community	0.09	2.71	3.24	0.90
6.	*Allium carolinianum - Elymus nutans - Cousinia thomsonii* mixed community.	0.14	2.33	2.45	0.81
7.	*Elymus nutans - Rhodiola tibetica - Berginia stracheyi* mixed community.	0.22	1.86	1.53	0.78
8.	*Lindelofia stylosa - Elymus nutans - Carex* sp. mixed community.	0.10	2.64	3.14	0.85
9.	*Lindelofia stylosa - Carex* sp.-*Allium carolinianum* mixed community.	0.14	2.28	2.23	0.82
10.	*Berginia stracheyi -Allium carolinianum - Rhodiola tibetica* mixed community.	0.13	2.42	2.44	0.82
11.	*Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community.	0.21	1.90	1.30	0.79
12.	*Elymus nutans - Tanacetum nubigenum - Christolea* mixed community.	0.19	1.81	0.97	0.93

(xi) *Calamogrostis* sp. *-Berginia stracheyi - Rheum tibeticum* mixed community

A perusal of Table 2 showed that total number of herbs species was 11. *Calamogrostis* sp. showed highest value for density/m^2 (40.00) followed by *Elymus nutans* (6.13), *Rheum tibeticum* (4.00) and lowest value (0.05) was observed for *Christolea himalayensis* (Table 2). Maximum frequency % was observed for *Calamogrostis* sp. (30.00) followed by *Elymus nutans* (20.00), *Androsace delavayi* (15.00) and *Rheum tibeticum* (15.00) and minimum value (2.00) was observed for *Christolea himalayensis* (Table 3). Maximum abundance was observed for *Calamogrostis* sp. (133.33) followed by *Elymus nutans* (30.63), *Rheum tibeticum* (26.67) and minimum value (2.50) was observed for *Christolea himalayensis* and *Rheum*

speciforme (Table 4). *Calamogrostis* sp. (115.74) was dominant species on the basis of IVI (Table 5) followed by *Berginia stracheyi* (48.34), *Rheum tibeticum* (39.04) and least dominant was *Christolea himalayensis* (1.97).

(xii) *Elymus nutans* - *Tanacetum nubigenum* - *Christolea* mixed community

A perusal of Table 2 showed that total number of herbs species was 7. *Elymus nutans* showed highest value for density/ m^2 (6.18) followed by *Tanacetum nubigenum* (1.78) and *Christolea crassifolia* (1.30) and lowest value (0.30) was observed for *Physochlaina praealta* (Table 2). Maximum frequency % was observed for *Tanacetum nubigenum* (35.00) followed by *Elymus nutans* (30.00) and minimum value (2.50) was observed for *Physochlaina praealta* (Table 3). Maximum abundance was observed for *Elymus nutans* (20.58) followed by *Physochlaina praealta* (12.00), *Askellia flexuosa* (6.60) and minimum value (3.83) was observed for *Alyssum desertorum* (Table 4). *Elymus nutans* (87.20) was dominant species on the basis of IVI (Table 5) followed by *Tanacetum nubigenum* (65.80), *Christolea crassifolia* (44.00) and least dominant was *Physochlaina praealta* (15.24).

Distribution pattern:

Contiguous distribution pattern was observed for all the herbs species in all the communities.

Concentration of dominance (C):

Maximum value of concentration of dominance (C) was 0.22 in *Elymus nutans* - *Rhodiola tibetica* - *Berginia stracheyi* mixed community followed by 0.21 in *Elymus nutans* - *Stipa capillata* - *Berginia stracheyi* mixed community and minimum value 0.09 in *Elymus nutans* - *Allium carolinianum* - *Arnebia euchroma* - *Berginia stracheyi* mixed community and *Elymus nutans* - *Allium carolinianum* - *Rheum spiciforme* mixed community (Table 6).

Diversity index (H):

Highest value of diversity index (H) was 2.84 in *Elymus nutans* - *Stipa* sp.- *Carex* sp. mixed community followed by 2.71 in *Elymus nutans* - *Allium carolinianum* - *Rheum spiciforme* mixed community and lowest was 1.81 in *Elymus nutans* - *Tanacetum nubigenum* - *Christolea* mixed community (Table 6).

Species richness index (R):

Maximum value of richness index (R) was 4.08 in *Elymus nutans* -*Stipa* sp.- *Carex* sp. mixed community followed by 3.24 in *Elymus nutans* - *Allium carolinianum* - *Rheum spiciforme* mixed community and minimum value was 0.97 in *Elymus nutans* - *Tanacetum nubigenum* - *Christolea* mixed community.

Evenness index (E):

Highest value of eveness index (E) was 0.93 in *Elymus nutans* - *Allium carolinianum* - *Arnebia euchroma* - *Berginia stracheyi* and *Elymus nutans* - *Tanacetum nubigenum* - *Christolea* mixed community followed by 0.90 in *Elymus nutans* - *Allium carolinianum* - *Rheum spiciforme* mixed community and minimum was 0.78 in *Elymus nutans-Rhodiola tibetica-Berginia stracheyi*in mixed community (Table 6).

V. DISCUSSION

Total 12 communities and 71 species of herbs were recorded in Kibber Wildlife Sanctuary. Total numbers of threatened plants were 4. The population of plants depends upon topography, altitude and habitats. (Arya and Samant, 2017; Arya and Samant, 2016; Rawat and Uniyal, 1993). The presence of threatened species in the landscape indicated that conservation and management of these species is important.

Total numbers of species in communities varied from 07 to 32. Highest total density/m^2 was 54.85 in *Calamogrostis* sp. -*Berginia stracheyi* - *Rheum tibeticum* mixed community and lowest was 7.35 in *Elymus nutans- Allium carolinianum- Lindelofia stylosa* mixed community. The density of the grasses was high in most of the communities which indicates the proliferation of these species in communities (Arya and Samant, 2017). The general distribution pattern of plants in the nature was contiguous and also reported by researchers (Verma *et al.,* 2003; Kershaw, 1973; Singh and Yadav, 1974 and Kunhikannan *et al.,* 1998). The Concentration of dominance (C) varied from 0.09 to 0.22. The lower value of dominance shows that there are many species which are dominant (Verma *et al.,* 2008). Diversity index (H) ranged from 1.81 to 2.84. Highest value of richness index (R) was 4.08 and lowest was 0.97. Highest value of evenness index (E) was 0.93 and lowest was 0.78. The value of diversity index (H) was in range as reported by (Arya and Samant, 2017 and Kala *et al.,* 1998). The evolutionary time and community stability are long term factors which effect the species diversity because diversification of different communities depend upon heterogenecity of macro and micro environment (Verma *et al.,* 2008).

VI. CONSERVATION STRATEGIES

Monitoring of threatened, endemic and economically important species should be done at regular interval. Promotion of *ex-situ* conservation of threatened, endemic and economically important species may be encouraged. Education and awareness programmes on the status and conservation of floristic diversity should be organised.

VII. CONCLUSIONS

The population dynamic of species should be regularly monitored for those species which have less density in Kibber Wildlife Sanctuary. The conservation and mangement strategies should be prepared especially for threatened species and plants of socio-economic importance.

ACKNOWLEDGMENTS

The authors are thankful to Director, Himalayan Forest Research Institute, Shimla for allowing to conduct the study. Authors are thankful to Himachal Pradesh State Forest Department (Wildlife) for funding to execute this study. The authors are thankful to assist in this study by Pankaj Sharma, Baldev and Kulwant Rai Gulshan. The authors are thankful to Dr G S Rawat ex Director, Wildlife Institute of India, Dehradun and Mrs. Usha Devi, Deptt of AYUSH, Delhi and Dr. M. K. Seth, Retired Professor, Himachal Pradesh University for helping in identification of the plants.

REFERENCES

Arya, S.C. and Samant, S.S. (2016). Habitat wise Assessment of Alpine vegetation and prioritization of communities for conservation in a part of Nanda Devi Biosphere Reserve of West Himalaya, India-I. *International journal of Life Sciences*, **5**(1): 6-19.

Arya, S.C. and Samant, S.S. (2017). Assessment of vegetation and prioritization of communities for conservation in Latakharak Alpine Meadows of Nanda Devi Biosphere Reserve, West Himalaya, India. *International journal of Advanced Research*, **5**(9): 1349-1366.

Bruno, J.F., Stachowicz, J.J., Bertness, M.D. (2003). Inclusion of facilitation into ecological theory. *Trends in Ecology and Evolution*, 1**8**: 119-125.

Curtis, J. T., & Cottam, G. (1950). *Plant Ecology Work Book: Laboratory, Field and Reference Manual*. Burgess Publishing Company.

Curtis, J.T. and Mclntosh, R.P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, **1**: 434-455.

Devi, U., Seth, M.K., Sharma, P. and Rana, J.C. (2013). Study on ethnomedicinal plants of Kibber wildlife Sanctuary: A cold desert in Trans Himalaya, India. *Journal of Medicinal Plants*, **7**(47): 3400-3419.

Gautam, A.K., Bhatia, M.K. and Bhadauria, R. (2011). Diversity and usage custom of plants of western Himachal Pradesh, India - Part I. *Journal of Phytology*, **3**(3): 24-36.

Goraya, G.S., Jishtu, V., Rawat, G.S. & Ved, D.K. (2013). Wild Medicinal Plants of Himachal Pradesh: An assessment of their conservation status and management prioritization. Himachal Pradesh Forest Department, Shimla. An outcome of the conservation assessment & management prioritization (CAMP) Workshop held at Shimla on 01-04 December, 2010.

Hill, M.O. (1973). Diversity and its evenness, a unifying notation and its consequences. *Ecology*, **54**: 427-432.

Joshi, S.P. and Srivastava, M.M. (1988). Effect of grazing on species composition, diversity and productivity in a high altitude pasture in Garhwal Himalaya. *Int. Jour. Enviro. Sci.*, **14**: 221-227.

Kala, C.P., Rawar, G.S. and Uniyal, V.K. (1998). *Ecology and conservation of the valley of flowers National Park, Garhwal Himalaya.* Report. Wildlife Institute of India, Dehradun.

Kapoor, K.S. (2004). Biodiversity in cold deserts of Western Himalayas. Discussion forum. Time Network, 17-21.

Kaul, V. and Sarin, Y.K. (1971). The phytosociology of some alpine meadows in North Wesr Himalaya. *Vegetation*, **23**: 261-368.

Kershaw, K.A. (1973). Quantitaive and dynamic plant ecology. Edward Arnold Ltd., London, UK.

Khanna, K.K. and Shukla, A.N. (2019). Some Angiosperms as new record for Uttar Pradesh, India. *Journal on New Biological Reports*, **8**(1): 22-26.

Kikvidze, Z., Pugnaire, F.I., Brooker, R.W., Choler, P., Lortie, C.J., Michalet, R., Callaway, R.M. (2005). Linking patterns and processes in alpine plant communities: a global study. *Ecology*, **86**: 1395-1400.

Kumar, Ranjeet, Verma, R.K., Thakur, C., Prakash, R. and Kumar, S. (2020). Diversity of Shrubs in Kibber Beat in Kibber Wildlife Sanctuary of Lahaul & Spiti District, Himachal Pradesh. *International Journal of Theoretical & Applied Sciences*, **12**(2): 1-8.

Kunhikannan, C., Ram K. Verma, K. Verma Raj, P.K. Khatri and Totey, N.G. (1998). Ground flora, soil micro flora and fauna diversity under plantation ecosystem on bhata land of Bilaspur, Madhya Pradesh. *Environment and Ecology*, **16**: 539-548.

Mallick, J.K. (2020). An annotated checklist of dicotyledonus angiosperms in Darjeeling Himalayas and foothills, West Bengal, India. *Journal on New Biological Reports*, **9**(2): 94-208.

Margalef, R. (1958). Temporal succession and spatial heterogeneity in phyto-plankton. In: A. A. Buzzati-Traverso. (Ed.). *Perspective in Marine Biology*. University of California Press, *Berkeley*, 323-347.

Negi, C.G.S., Rihari, H.C. and Singh, S.P. (1992). Phenological features in relation to growth forms and biomass accumulation in an alpine meadow of the central Himalaya. *Vegetation*, **101**: 161-170.

Negi, J.P. (1985). Development perspectives in the Himalayan Mountain Desert of Spiti (Himachal Pradesh) greening the Mountain Deserts. In Special lecture delivered at 72nd session of the Indian Science Congress Association, Lucknow University, Lucknow.

Negi, R., Baig, S., Chandra, A., Verma, P.K., Naithani, H. B., Verma, R. & Kumar, A. (2019). Checklist of family Poaceae in Lahaul and Spiti district (Cold Desert), Himachal Pradesh, India. *Plant Science Today*, **6**(2): 270-274.

Rana, M.S., Samant, S.S., and Rawat, Y.S. (2011). Plant communities and factors responsible for vegetation pattern in an alpine area of the Northwestern Himalaya. *Journal of Mountain Science*, **8**: 817-826.

Rawat, G.S. and Uniyal, V.K. (1993). Pastoralism and plant conservation. The valley of flowers dilemma. *Environmental Conservation*, **20**: 164-167.

Rawat, G.S., and Pangtey, Y.P.S. (1987). Floristic structure of snowline vegetation in central Himalaya, India. *Arctic and Alpine Research*, **19**(2): 195-201.

Samant, S.S., Joshi, H.C., Arya, S.C., & Pant, S. (2002). Studies on the structure, composition and changes of the vegetation in Nanda Devi Biosphere Reserve of West Himalaya. *Biosphere Reserves in India and their Management. New Delhi: Kerala Forest Research Institute and Ministry of Environment and Forests*, 133-139.

Sharma, L., and Samant, S.S. (2019). Prioritization of habitats and communities for conservation in Cold Desert Biosphere Reserve, Trans Himalaya, India. *Ecological Research*, 1-15.

Saxena, S., Bhardwaj, A.K., Kumar, V., Patel, M.K., Kumar, R. and Chaurasia, O. P. (2018). Sustainable Utilisation of Medicinal Plants of Ladakh and

Lahaul-Spiti of trans-Himalaya. *Defence Life Science Journal*, **3** (2): 120-125.

Shannon, C.E. and Wiener, W. (1963). The Mathematical Theory of Communication. Univ. of Illinois Press. Urbana, U.S.A.

Sharma, Pankaj and Mishra, N.K. (2009). Diversity, utilization pattern and indigenous uses of plants in and around a cement factory in Bilaspur district of Himachal Pradesh, North-Western Himalaya. *Biological Forum — An International Journal*, **1**(2): 89-91.

Simpson, E.H. (1949). Measurement of diversity. *Nature*, **163**(4148): 688-688.

Singh, K.N. (2008). Ecological studies on landscape elements, species diversity and ethnobotany of higher plants in Lahaul-Spiti region of Western Himalaya. Ph.D. thesis. HNB University, Garhwal, India.

Singh, J.S. and Yadava, P.S. (1974). Seasonal variation in composition, plant biomass and net primary productivity of a tropical grass land at Kurukshetra, India. *Ecological Monographs*, **44**: 357-375.

Srivastava, S.K. (2010). Biodiversity profile-Floristic diversity and conservation strategies in cold desert of western Himalaya, India. *Botanica Orientalis – Journal of Plant Science*, **7**: 18–25.

Tewari, V.P. and Kapoor, K.S. (2013). Western Himalaya cold desert: Biodiversity, eco-restoration, ecological concerns and securities. *Annals of Arid Zone*, **52**(3&4): 223-230.

Tilman, D., Reich, P.B., Knops, J., Wedin, D., Mielke, T., Lehman, C. (2001). Diversity and productivity in a long term grassland experiment. *Science*, **294**: 843-845.

Veech, J.A. (2003). Incorporating socioeconomic factors into the analysis of biodiversity hotspots. *Applied Geography*, **23**: 73-88.

Verma, R.K. and Kapoor, K.S. (2010). Assessment of floristic diversity in Pooh valley of cold desert of district Kinnaur, Himachal Pradesh. *Biological Forum- An International Journal*, **2**(1): 35-44.

Verma, R.K., Jishtu, V. and Kapoor, K.S. (2008). Plant species diversity in Labrang valley of cold desert in District Kinnaur, Himachal Pradesh. *Environment & Ecology*, **26**(2), 505-516.

Verma, R.K., Jishtu, V., Kapoor, K.S. and Subramani, S.P. (2003). Analysis of Plant Diversity in Man Lunga Valley and Khamengar Valley of Pin Valley National Park in Himachal Pradesh. *Environment & Ecology*, **21**(4): 941-946.

Verma, R.K. (2015). Assessment of Floristic Diversity in Khajjiar beat of Kalatop Khajjiar Wild Life Sanctuary of district Chamba, Himachal Pradesh. *Bio Bulletin*, Vol. **1**(1): 12-21.

Verma, R.K. and Kapoor, K.S. (2014). Status of Plant Diversity in Alpine Area of Rakchham- Chitkul Wild life Sanctuary of District Kinnaur, Himachal Pradesh. *Biological Forum–An International Journal*, **6**(1): 5-12.

Verma, R.K. and Kapoor, K.S. (2010). Assessment of floristic diversity in Pooh valley of cold deserts of District Kinnaur, Himachal Pradesh. *Biological Forum – An International Journal*, **2**(1): 35-44.

Verma, R.K. (2016). Status of Plant Diversity along an Altitudinal Gradient in Dankund Beat of Kalatop Khajjiar Wild Life Sanctuary of District Chamba, Himachal Pradesh. *Biological Forum – An International Journal*, **8**(1): 540-547.

Verma, R.K. (2017). Phyto-diversity studies in Kanasa Valley of Rakchham Chitkul Wild life Sanctuary of District Kinnaur, Himachal Pradesh. *Biological Forum – An International Journal*, **9**(1): 62-69.

Verma, R.K., Kapoor, K.S., Subaramani, S.P. and Jishtu, V. (2003a). Assessment of Plant speices diversity in *Betula utilis* D. Don Forest in Cold Arid Region of Himachal Pradesh. *Environment & Ecology*, **21**(4), 922-927.

How to cite this article: Kumar, R., Verma, R. K. Kumar, S., Thakur, C., Prakash, R., Kumari, K., Dushyant and Yadav, S. (2020). Diversity of herbs in Kibber Wildlife Sanctuary of Distt. Lahaul and Spiti, Himachal Pradesh. *Biological Forum – An International Journal*, **12**(2): 01-12.