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PHYTOGEOGRAPHIC ANALYSIS AND DIVERSITY OF GRASSES AND SEDGES (*POALES*) OF NORTHERN PAKISTAN

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Abstract

The monocot order *Poales* is one of the largest (ca. 20,000 species), and economically and ecologically most important group of flowering plants. Exploring this important component of the biodiversity is of paramount significance in conservation of species and developing climate change models. Northern Pakistan occupies a unique biogeographic position at the summit of the planet's three highest mountain ranges i.e.Himalaya, Hindukush and Karakurum.These ranges contain the hot spots of floral and faunal diversity with high proportions of endemic and rare species.The studies revealed 117 species belonging to 30 genera in three families of the order *Poales*. *Juncaceae* is represented by single genus *Juncus*with four species, *Cyperaceae* by 5 genera and 27 species, and *Poaceae* being the dominant family with 25 genera and 86 species. *Carex*and *Poa*are the largest genera having 21 and 16 species respectively. Phytogeographic analysis of the *Poales*of temperate and alpine regions of Northern Pakistan shows twelve different phytogeographic elements. The highest percentage of species (30%) belongs to the western Himalayan floristic region (near endemics), with cosmopolitan elements (19%), Central Asian elements (17%) and Eurasian elements (12%) being the other significant elements. The proportion of Endemic species (8%) is less apparent, while the rest of the seven categories are poorly represented. The Two Way Cluster Analysis (TWCA) divided the sixteen districts into two major groups, and four subgroups based on environmental gradients of altitude, latitude and longitude. TWCA classified the data matrix including 114 species into seven clusters based on presence/absence data and elevation from mean sea level. Species in each cluster can be attributed to similar habitat conditions and altitudinal ranges. Hence it is clear that climatic characters associated with each category control the species distribution pattern.

Key Words: Phytogeography, Floristic elements, Diversity, Grasses, Sedges, Northern Pakistan

Introduction

Plant species are neither evenly nor randomly distributed on the surface of the earth, but rather in definite geographic units, governed so by the physical environment and climate (Qian, 2001). Factors affecting the spatial distribution of species include both abiotic and biotic factors, such as soil, topography, geology, tectonic movements, mountain uplifting, climate change and species evolution and migration. Analysis of the distribution patterns of plants (phytogeography) is extremely valuable in perception of the ecological nature of a region and its plants wealth. Geographic analysis of plants is of utmost importance in tracing the origin of particular flora, its range of distribution, evolution and diversification. Floristic inventories and phytogeographic patterns of vegetation provide an understanding of plant species diversity and management plans for their conservation (Harris *et al.,*, 2012; Qian, 2001). Such studies are also very useful in the context of the global climate change and its biological impacts (Grabherr *et al.,*, 1995; Körner, 2003; Wilson *et al.,* 2007).

A useful approach for characterization of flora of a region and knowing its biogeographical affinities with flora of other regions is to classify its component taxa in to phytogeographic elements (Qian *et al.,*, 2006; Stott, 1981). Using this quantitative phytogeographic approach Takhtajan (1986) identified 5 floristic provinces in Pakistan. These are Sindian province, Southern Iranian province, Northern Baluchistan province, Western Himalayan province and Tibetan province. The flora of Northern Pakistan has geographic affinities with Central Asia, extending in the west from Turkey to the Gobi desert in the east. The western Himalaya is considered as the most species rich and dominant province with greater number of endemic taxa. This province represents a transition between the ancient Mediterranean and eastern Asiatic floras.

There are several studies exist on the subject underpinning different regions of the globe. For instance, Ocak *et al.,* (2009) studied the floristic affinities and conservation status of wild *Poaceae*species from Malatya province Turkey. The Irano-Turanian elements were dominant with 28.7%, followed by Mediterranean and Euro-Siberian regions. Noroozi*et al.,* (2008) analyzed the alpine flora of Iran that occur above 4000 m, and reported 682 species in 39 families. They found that the flora of Iranian alpines is a transition of Anatolia, Caucasus and the Hindu Kush, with a strong (58%) endemism. Dávila-Aranda *et al.,* (2004) discussed the distribution pattern of Mexican endemic grasses. Garcia *et al.,* (2009) compared distribution of 224 species of grasses of Brazilian *Campos* based on climate and geographic position. Haq *et al.,* (2011) studied the diversity and distribution pattern of cosmopolitan genus *Carex* L. from Kashmir Himalayas. Ullah*et al.,* (2013) studied the phylogeny of genus *Carex* from Northern Pakistan and found its origin from central Asian elements. The distribution pattern and endemism of family *Crassulaceae* from Pakistan and Kashmir were investigated by (Sarwar & Qaiser, 2012) and concluded

that 15 taxa are of Irano-Turanian affinity, 16 are Sino-Japanese elements and only one is Mediterranean element. Breckle (1974) evaluated phytogeographic pattern of the alpine and nival vegetation of Afghanistan and stated that the flora has a close relationship with Central Asian plants.

There are few sporadic phytogeographic studies dealing with the flora of Northern areas of Pakistan. The high alpine region of Northern Pakistan is botanically and ecologically poorly investigated (Khan *et al.,* 2013a & b). In comparison to the lowland areas there are still little in-depth studies, which deal with the alpine flora and biodiversity (Shaheen *et al.*, 2011). No scientific study arise de novo. The major goal of this work is to provide a detailed study of the grasses and sedges which are distributed in the alpine and temperate region of Northern Pakistan, with focus on distribution pattern and phytogeographic relationship with the rest of the world. A second goal of the study is to analyze the endemism and propose the origin of the flora of the region.

Material and Methods

Data gathering: The distribution pattern of species belonging to the order Poales for Northern Pakistan (Fig. 1) that occurs in the alpine and temperate region (2000 m, a.s.l) is based primarily on the extensive field excursions between 2008 and 2013. The species were studied in their natural habitats, and geographic coordinates, altitudes, habitat type and aspect of occurrence were recorded for each species. In addition to this, information on species distribution were extracted from the specimens housed in the following herbaria: ISL, E, K, BM, KUH, RAW and US, acronyms after (Holmgren *et al*., 1990). Most of the information has been drawn from comprehensive literature (Chen *et al*., 2006; Clayton *et al*., 2006 onwards; Cope, 1982; Jafri, 1981; Kukkonen, 2001; Renvoize *et al*., 2007; Simon *et al*., 2011; Soreng *et al*., 2009; Stewart, 1972; Tutin, 1993; Watson & Dalwitz, 1992). Information was also extracted from the Royal Botanic Garden Edinburgh Herbarium Catalogue, TROPICOS (Missouri Botanical Garden), and Global Biodiversity Information Facility (GBIF) online databases.

Data analysis: Based on our results extracted from survey of detailed literature, monographs, floras and personal experience, a set of 11 floristic elements were identified, as described in Table. 1. The description and classification of floristic elements are based on (Brummitt *et al*., 2001). The map of Northern Pakistan (Fig. 1) illustrates the position and geographic coordinates of all the 16 districts included in the present study. These districts includes 1) Ghanche, 2) Skardu, 3) Astore, 4) Diamer, 5) Hunza-Nagar, 6) Gilgit, 7) Ghizer, 8) Chitral, 9) Dir, 10) Swat, 11) Kohistan, 12) Mansehra, 13) Abbotabad 14) Neelum, 15) Muzaffarabad and 16) Bagh.

The presence/absence and elevation data for each species was recorded and arranged in EXCEL spreadsheets and analyzed. The analyses were done through multivariate statistics in PC-ORD version 5 (McCune & Mefford, 1999). In order to find out the pattern of distribution of species along the altitudinal gradient Two Way Cluster analysis (TWCA) using Sorensen measures was subsequently applied to the data (Greig-Smith, 2010). The cluster analysis, group similar entities together in a single cluster and result in a dendrogram.

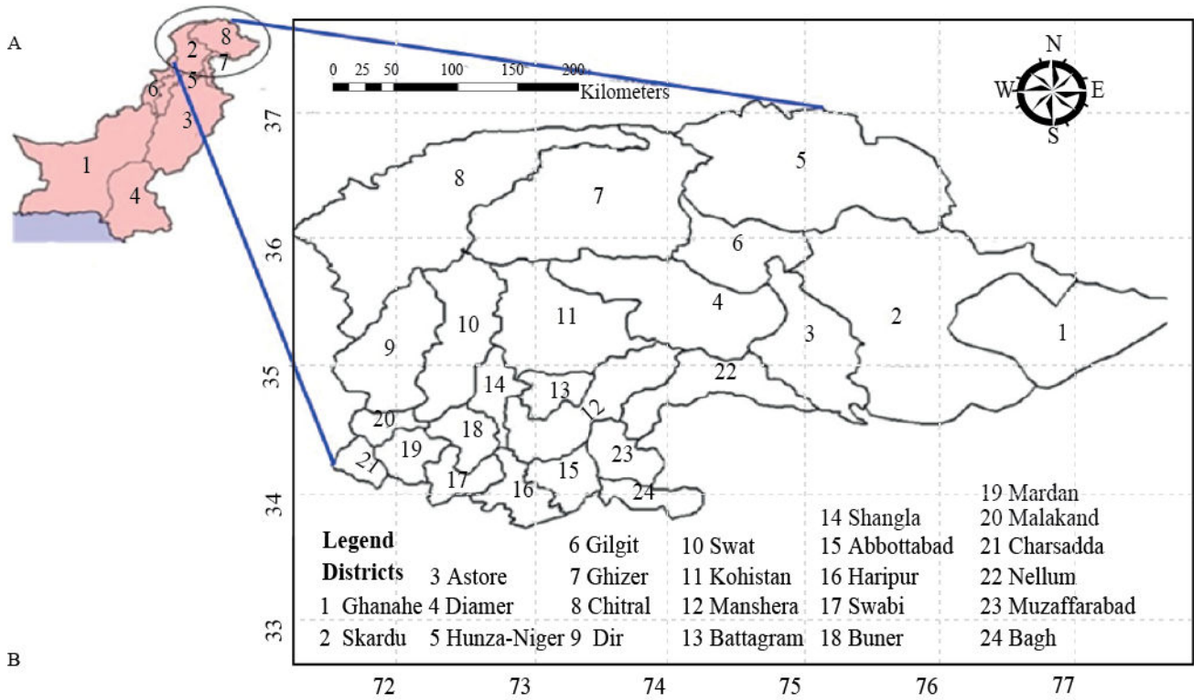

Fig. 1. (A) Reference map of Pakistan (B) Map of Northern Pakistan, showing location of the representative districts with geographic coordinates.

Table. 1. Definitions of floristic elements.

No.	Floristic Element	Distribution
1	Cosmopolitan	These are species with worldwide distribution on all or almost all continents.
2	Pantropical	Occurring in and around the tropical and subtropical regions of the world, some taxa may extend to temperate region.
3	Palaeotropical	Distributed in the tropics of Asia, Australia and Africa, also called old-world's tropics.
4	Holarctic	Taxa distributed primarily in the cold temperate regions of Europe, Asia and North America (Northern Hemisphere).
5	Circum Polar	Occurring in the polar regions of both the hemisphere.
6	Western Himalayan	Species with centre of diversity in NW Himalayas, however occasionally may extend eastward to eastern Himalayas or northwards to central Asia and Afghanistan.
7	Eurasian	Widely distributed across the temperate zone of Europe and Asia. Some of them may extend into the northernmost part of Africa.
8	Irano-Turanian	Taxa with centre of diversity in western Asia: Mesopotamia, Anatolia, Irano-Armenia and extends up to Tien-Shan.
9	Central Asian	These elements are distributed in the temperate central Asia, Caucasus, Tien-shan, Siberia and western Asia; with distribution centers mainly in temperate Asia but some species may occasionally extend to subtropical regions.
10	Mediterranean	Taxa distributed across the Mediterranean region in southern Europe, western Asia, and North Africa.
11	African	Species occurring in central tropical Africa and may extend northeastward to the Himalayas.
12	Endemic	Species which are restricted to the Northern Pakistan and adjoining Kashmir.

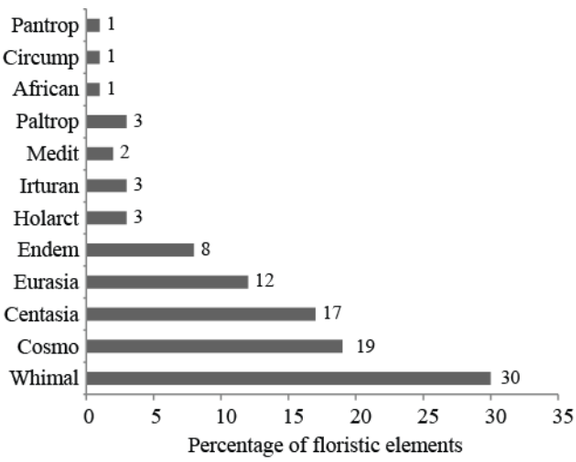

Fig. 2. Categories of floristic elements and phytochorion distribution pattern for the grasses, sedges and rushes of alpine and temperate region of Northern Pakistan.

Results and Discussion

Floristic elements: The present study is based on members of the order *Poales*(grasses, sedges, rushes)that are distributed 2000m above the mean sea level in Northern Pakistan (Fig. 1). The data set included 117 species, in 29 genera and three families, *Poaceae, Cyperaceae*and *Juncaceae.* Grasses contributed the major portion in the data set (73.50%), while sedges (23.07%) and rushes (3.41%) are less apparent. The distribution ranges of these species vary between 2000m and 5000m elevation in the alpine and nival region of Northern Pakistan. The checklist of species (Table 2) shows that *Carex*and *Poa*are the most speciose genera having 21 species and 16 species respectively. *Elymus*has 10 species, *Agrostis, Bromus* and *Festuca* have 7 species, and *Calamagrostis*and*Piptatherum* have 6 species each.

The present analysis recognized 12 different phytogeographic or floristic elements (Fig. 2 and Table. 2). The highest percentage of elements 30% (35 species) belong to the western Himalayan floristic province. The cosmopolitan elements represent 19% (22) and the Central Asian elements represent 17% (20). There are 12% (14) species of Eurasian origin and 9 species (8%) are endemic to the present study area. The dominance of W. Himalayan elements can be attributed to dispersal mechanisms and geological activities, which have given rise to local endemism. These species have their centre of diversity in the N.W Himalayas but some of them extend eastwardly to the eastern Himalayas, and westward to the central Asia and Eastern Europe. According to Takhtajan (1986) the flora of this province is transitional between the ancient Mediterranean and eastern Asiatic floras. Most of these elements are near endemic (partim endemic) in this region e.g*Calamagrostisscabrescens, Carexcardiolepis, C. duthiei, C. remota, Hierochloelaxa, Isachnehimalaica, Phleumhimalaicum, Piptatherummunroi, Poahimalayana, P. stapfiana*and *Stipahimalaica.* These species are distributed in wet forests under storey of temperate coniferous forests among other herbs.Such areas receive the monsoon rains during summer and heavy snowfall in winters; the plants renew growth at the approach of spring in March-April. Hayat (2011) also found the dominance of W. Himalayan elements (50%) in *Artemisia* of Pakistan. Ali & Qaiser (1986) also attributed 46% elements of flora of Pakistan to the Himalayan region.

The second largest proportion of elements (19%) belongs to the cosmopolitan category (Fig. 2). These species are found throughout the world in similar habitats and have vast ecological amplitude. According to (MacArthur, 1972) some tropical taxa penetrate into northern floras primarily due to the availability of suitable habitats rather than similar latitudes. Most of the species in this category occur at lower altitudes and are also found in

plains of the country, hence having tropical and subtropical distribution. Central Asian elements account for (17%) and Eurasian elements account for (12%) of the floristic composition (Fig. 2). The W. Himalayan elements together with Eurasian and central Asian components account for 60% of the floristic composition. All these elements are placed in the Holarctic Kingdom of Northern Hemisphere. Hence it is concluded that the phytogeographic elements of grasses, sedges and rushes of northern Pakistan have Holarctic origin. This view has also been proposed by Takhtajan (1986) and Ali &Qaiser (1986). The migration and exchange of species between mountains of Eurasia, the Alps, the Carpathians, the Caucasus, the Central Asian mountains, Altai and Himalayas during glacial periods are responsible for similarity between W. Himalayan and central Asiatic-Eurasian floras (Breckel, 1974).The plants of the coastal area of the Tethys Sea (ancient Mediterranean) and the plants of Laurasia (paleoasia) migrated into the Himalayan ranges when the Indian plate joined Laurasia and the Tethys Sea receded (Rongfu, 1988). The central Asian elements have their centre of diversity in temperate Asia and extend eastward into Europe and westward into the western Himalayas and adjoining China. The main areas of distribution include the Caucasus, Tien-shan, Siberia and western Asia. The Eurasian elements are distributed across the temperate zone of Europe and Asia and some of them may extend into the northernmost part of Africa.

The proportion of endemic species in the strict sense is relatively low, only 9 species (8%) in the present study area (Table 2 and Fig. 2). However the near endemic species of the western Himalayan category when incorporated would result in an increase in the percentage of endemic taxa. But we have considered only those species as endemics which are restricted to the northern Pakistan and Kashmir. The endemic species belong to only 4 genera *Calamagrostis* (2 species), *Festuca* (2 species), *Elymus* (4 species) and *Piptatherum* (1 species). The four species of *Elymus*include *Elymusborianus, E. dentatus, E. swatianus*and *E. kurramensis. E. borianus* are restricted to upper Swat, while *E. kurramensis* is endemic to a narrow belt from Kurram to Chitral (Cope, 1982). *E. swatianus* is a new species resulting from the present study, and is found at one place near Matta in Swat district. The endemic species of *Elymus*, *Festuca* and *Piptatherum* are found at lower altitudes in moist temperate forests. This distribution pattern support the view of (Akhani, 2007; Noroozi *et al.*, 2008) who found that endemism is higher at relatively low altitudes and decreases with increasing elevation.

The other six areal types are represented by lower percentages e.g Holarctic (3%), Irano-Turanian (3%), Mediterranean (3%), Paleotropical (2%), African (1%), and Circumpolar (1%) (Fig. 2).

Two way cluster analysis (TWCA) of sites (OGU's): The study area is situated between 34° and 37° N latitudes and 71.4° and 77.6° E longitudes. The TWCA divided the 16 districts (Operational Geographic Units; OGU's) into two large clusters i-e cluster A and cluster B, each of which further consists of 8 districts (Fig. 3). The 8 districts classified in "cluster A" are Ghanche, Skardu, Astor, Diamer, Gilgit, Hunza-Nagar, Ghizer and Chitral. These districts are northern and north-eastern in position on the map (Fig. 1). These areas are characterized by harsh climate and severe winters and snowfall. The mean annual rainfall in these areas is below 250 mm. The snowfall mostly occurs above 4,000 m and increases with altitude. These areas are classified as snow deserts (Breckle, 1974), with scattered cushion vegetation. The monsoon rain do not reaches to these districts and are blocked by the lofty Himalayan Mountains. The climate of this region is classified as arid to semi-arid and windy (Hashmi, 1998). Cold increases with increase in altitude. For every 100 m increase in elevation, temperature falls by one degree. The snow accumulates into glaciers above the snow line. These harsh climatic conditions and intense solar radiations result in xeric conditions hence β–diversity of species gradually decreasing both along the altitudinal and latitudinal gradients (Khan *et al*., 2011).

Cluster B comprising of 8 districts i.e. Dir, Swat, Kohistan, Mansehra, Abbotabad, Bagh, Muzaffarabad and Neelum. The geographic location of these districts is Southern (Fig. 1). This group of districts has relatively lower heights, with alpines between 2900 and 4000m. Monsoon rain reaches here, and annual rainfall reaches to 1700 mm, with above 80% relative humidity. Snow fall occur during winters but the summers are mild. Himalayan moist temperate forests are prevailing here. The vegetation is thick and biologically more diverse. The alpines in these districts have more species per unit area than that of the upper northern districts. This is because with decrease in elevation species richness increases (Breckel, 1974, Khan *et al.,* 2011, Shaheen *et al.,* 2012).

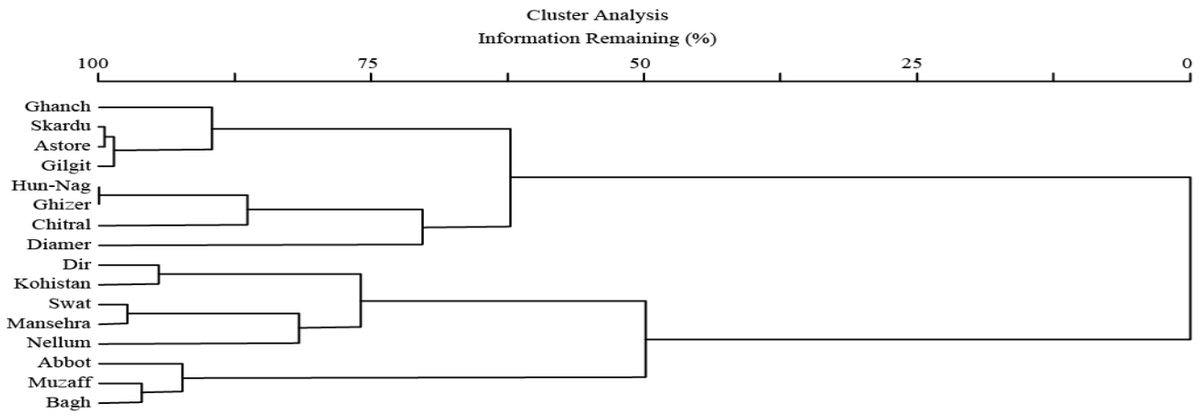

Fig. 3. Cluster dendrogram of 16 districts, using Sorenson similarity values.

Table 2. Distribution and centers of diversity of the grasses, sedges and rushes.

No.	Taxa	Distribution
1	*Agrostis gigantea* Roth	Europe, South Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, North America, South America, Subantarctic islands/COSMO.
2	*Agrostis hissarica* Rozhev.	Asia-temperate, Central Asia, Afghanistan, China, Western Himalaya Pakistan, India/CENTASIA.
3	*Agrostis munroana* Aitch. & Hemsel.	Temperate W. Asia, China, Western Himalaya/WHIMAL.
4	*Agrostis pilosula* Trin.	Asia-temperate, China, Western Himalaya/WHIMAL.
5	*Agrostiss tolonifera* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
6	*Agrostis vinealis* Schreb.	Europe, Asia-temperate, Western Asia, China, Western Himalaya India, Pakistan/EURASIA.
7	*Agrostis viridis* Gouan	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America/COSMO.
8	*Alopecurus aequalis* Sobol.	Europe, Asia, Australasia, North America, South America, absent from Africa/COSMO.
9	*Alopecurus arundinaceus* Poir.	Europe, Asia-temperate, China, and Mongolia; Western Himalaya India, Pakistan/EURASIA.
10	*Alopecurus himalaicus* Hook.f.	Europe: southeastern, Western Asia, and China, Western Himalaya India, Pakistan/WHIMAL.
11	*Blysmus compressus* (Decne.) Kukkonen	Europe, N. Africa, temperate Asia, Central Asia, western Asia, China, Pakistan, India, Nepal, Bhutan/EURASIA.
12	*Bromus catharticus* Vahl	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
13	*Bromus hordeaceus* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
14	*Bromus inermis* Leyss.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America/COSMO.
15	*Bromus japonicas* Thunb.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America/COSMO.
16	*Bromus pectinatus* Thunb.	Africa, Asia-temperate, Soviet Middle Asia, western Asia, Arabia and China, India, Pakistan/AFRICAN
17	*Bromus oxyodon* Schrenk	Asia-temperate, Central Asia, Afghanistan, China, Mongolia, Western Himalaya Pakistan, India/CENTASIA.
18	*Bromus ramosus* Huds	Europe, North America, temperate Central and Western Asia, China, Western Himalaya Pakistan, India/EURASIA.
19	*Calamagrostis decora* Hook. f.	Western Himalaya Pakistan/ENDEM.
20	*Calamagrostis emodensis* Griseb.	Temperate western Asia and China, Western Himalayas Pakistan and India/WHIMAL.
21	*Calamagrostis epigejos* (L.) Roth	Europe, Africa, Asia-temperate, Asia-tropical, Australasia, North America/COSMO.
22	*Calamagrostis pseudophragmites* (Hall.f.) Koel.	Europe, Asia temperate, Central and Western Asia, China, Western Himalaya Pakistan, India/EURASIA.
23	*Calamagrostis scabrescens* Griseb.	Western Himalayas Pakistan, Kashmir, China/WHIMAL.
24	*Calamagrostis stoliczkai*Hook. f.	Western Himalaya Pakistan, Kashmir/ENDEM.
25	*Carex atrofusca* Schkuhr	Arctic circum-polar, Europe, Central Asia, NE Afghanistan, N Pakistan and Himalayas/EURASIA
26	*Carex canescens* L.	Boreal circum-polar, C. Asia extending eastwards to Pakistan and Kashmir; also New Guinea, Australia and S. America/CIRCUMP.
27	*Carex cruciate* Wahlenb	From Madagascar, Kashmir and India to Taiwan and Indonesia/PALTROP.
28	*Carex cardiolepis* Nees	From Afghanistan, Pakistan, Kashmir to N. India /WHIMAL.
29	*Carex divisa* Hudson	WS Europe, N. Africa, western Asia, Central Asia, Pakistan to Kashmir and E Myanmar; introduced in N. America, South Africa and New Zealand/MEDIT.

Table 2. (Cont'd).

No.	Taxa	Distribution
30	*Carex divulsa* Stokes	China, India, Indonesia, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Vietnam/PALTROP.
31	*Carex duthiei* C. B. Clarke	From N Pakistan to Sikkim and Central China/WHIMAL.
32	*Carex fedia* Nees	From India, Pakistan, Afghanistan and Pamiro-Alai to Central China and Thailand/WHIMAL.
33	*Carex filicina* Nees	China, India, Indonesia, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Vietnam/PALTROP.
34	*Carex foliosa* D. Don	Pakistan, eastwards to Assam; in S. India/WHIMAL.
35	*Carex inanis* C. B. Clarke	Pakistan, Kashmir, NE India, Nepal, Bhutan, China/ WHIMAL.
36	*Carex infuscata* Nees	Asia temperate, Central Asia, Siberia, China, Mongolia, Afghanistan, NW Pakistan/CENTASIA.
37	*Carex melanantha* C. A. Mey.	Asia temperate, Central Asia, Siberia, China, Mongolia, Afghanistan, NW Pakistan, India/CENTASIA
38	*Carex nivalis* Boott	From Central Asia through Afghanistan, to NW Pakistan, Kashmir, India, Nepal/WHIMAL.
39	*Carex otrubae* Podpera	Europe, Temperate middle Asia, Siberia, to N Pakistan/EURASIA.
40	*Carex pseudocyperus* L.	Europe, N. America, Mediterranean, N. Africa, Caucasus, Siberia, C. Asia, China, eastern Asia, W Asia, to Kashmir/HOLARCT.
41	*Carex psy chrophila* Nees	E Afghanistan to Kashmir, Himalayas, China/WHIMAL.
42	*Carex remota subsp. Stewartii* Kukkonen	E Afghanistan to Garhwal, Uttar Pradesh/WHIMAL.
43	*Carex sanguinea* Boott	Afghanistan and Pakistan, eastwards into Kashmir/ WHIMAL.
44	*Carex schlagintweitiana* Boeck.	From Pakistan to Himachal Pradesh, India/WHIMAL.
45	*Carex songorica* Kar. &Kir.	Russia, C. Asia, western Asia, Afghanistan, N. Pakistan India, China, NW Mongolia/CENTASIA.
46	*Dactylis glomerata* L.	Temperate Europe and Asia, Mediterranean, introduced into many temperate parts of the world/EURASIA.
47	*Deschampsia koelerioides* Regel	Asia-temperate, central Asia, western Asia, China, and Mongolia, Western Himalaya Pakistan, Kashmir/ CENTASIA.
48	*Eleocharis quinquflora* (F.X. Hartm.) O.Schwarz	Europe, NW Africa, temperate Asia, Western and Central Asia, east to Nepal, China/ HOLARCT.
49	*Eleocharis palustris* (L.) Roem. & Schult.	E Turkey, Iraq, Iran, Afghanistan, Pakistan/IRTURAN.
50	*Elymus borianus* (Meld.) T. A. Cope	Western Himalaya Pakistan/ENDEM.
51	*Elymus caninus* L.	Europe, Asia temperate, Western Asia, Eastern Asia, Western Himalayas, Subarctic North America/EURASIA.
52	*Elymus dahuricus* Turcz. ex Griseb.	Europe eastern, Asia-temperate: Siberia, western Asia, China, Mongolia, and eastern Asia to Western Himalayas in Pakistan and India/CENTASIA.
53	*Elymus dentatus* (Hook.f.) T. A. Cope	Western Himalaya Pakistan, Kashmir/ENDEM.
54	*Elymus kuramensis* (Meld.) T.A. Cope	Kurram valley Pakistan/ENDEM.
55	*Elymus longe-aristatus* (Nevski) Tzvelev	Temperate Asia: Central Asia, Iran, Afghanistan, China, India, Pakistan/CENTASIA.
56	*Elymus nutans* Griseb.	Central Asia, Western Asia, China, Mongolia, Northwest Pakistan and India/WHIMAL.
57	*Elymus repens* (L.) Gould	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
58	*Elymus semicostatus* (Nees ex Steud.) Meld.	Afghanistan through Western Himalayas to Sikkim India/WHIMAL.
59	*Elymus swatianus* Z. Ullah ex M. Ahmad	Swat Pakistan/ENDEM.
60	*Eremopoa altaica* (Trin.) Rozhev.	E. Europe, N. Africa, Asia-temperate, Siberia, Caucasus, Western Asia, Central Asia and China to Western Himalayas Pakistan and India/CENTASIA.

Table 2. (Cont'd).

No.	Taxa	Distribution
61	*Festuca alaica* Drobov	Asia-temperate: Soviet Middle Asia, Central Asia to Afghanistan and Western Himalaya/CENTASIA.
62	*Festuca asthenica* Hook. f.	Kashmir Western Himalaya/ENDEM.
63	*Festuca gigantean* (L.) Vill.	Europe, Asia-temperate: Siberia, Soviet Middle Asia, Caucasus, western Asia, and China to Western Himalayas/EURASIA.
64	*Festuca hartmannii* (Markgr.-Dannenb.) Alexeev	Pakistan and Kashmir/ENDEM.
65	*Festuca kashmiriana* Stapf	China and Northwestern Himalayas India, Pakistan/ WHIMAL.
66	*Festuca olgae* (Regel) Krivot.	Asia-temperate, western Asia and China, India, Pakistan/ CENTASIA.
67	*Festuca rubra* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
68	*Fuirena pubescens* (Poir.) Kunth	N. Africa, Mediterranean from Portugal to Turkey, Afghanistan, NW Himalayas India, Pakistan/MEDIT.
69	*Helictotrichon pratense* (L.) Pilger	Europe, temperate Asia/EURASIA.
70	*Helictotrichon virescens*	North Western Himalayas east wards to Sri Lanka, Burma and Malaysia/WHIMAL.
71	*Hierochloë laxa* R. Br. ex Hook f.	Northwestern Himalaya in Pakistan, Kashmir and India/WHIMAL.
72	*Isachne himalaica* Hook. f.	Afghanistan, Bhutan, Northern India, Nepal, Pakistan/WHIMAL.
73	*Juncus articulatus* L.	Europe, N. Africa, Central and S.W. Asia, to Pakistan and the Himalayas, N. America, introduced in Australia and New Zealand/EURASIA.
74	*Juncus bufonius* L.	Europe, North and South America, Central Asia, Western Asia, eastern Asia, China, Mongolia, tropical Asia, SW Asia/PANTROP.
75	*Juncus membranaceus* Royle ex D. Don	Afghanistan, Pakistan, India, Nepal, China/WHIMAL.
76	*Juncusm aritimus* Lam.	Europe, Mediterranean, N. Africa, temperate and tropical Asia, N. America, introduced elsewhere/MEDIT.
77	*Kobresia laxa* Nees	Afghanistan, Tajikistan eastwards to Nepal and Sikkim/WHIMAL.
78	*Kobresia schoenoides*(C. A. Mey.) Steud.	Central Asia, Caucasus, Afghanistan, Pakistan, India, Nepal to Tibet China/CENTASIA.
79	*Leymus secalinus* (Georgi) Tzvelev	Asia-temperate, central Asia, Soviet middle Asia, eastern Asia, Northwest India, Pakistan/CENTASIA.
80	*Lolium perenne* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
81	*Melica persica* Kunth	Asia-temperate, western Asia, Arabia, and China, India, Pakistan/IRTURAN.
82	*Milium effusum* L.	Europe, Asia-temperate, Siberia, western Asia, eastern Asia, India, Pakistan, North America/HOLARCT.
83	*Pennisetum flaccidum* Griseb.	Asia-temperate, western Asia, China, and Mongolia, Western Himalaya Kashmir, Pakistan/WHIMAL.
84	*Pennisetum lanatum* Klotzsch	From Afghanistan eastward through Himalayas Pakistan, India, Nepal to Tibet China/WHIMAL.
85	*Phleum alpinum* L.	Europe, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
86	*Phleum himalaicum* Mez	Afghanistan to Western Himalayas/WHIMAL.
87	*Phleum paniculatum* Huds.	Europe, Asia-temperate, Soviet Middle Asia, western Asia, China, and eastern Asia, NW Pakistan and India/EURASIA.
88	*Phleum pretense* L.	Europe, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
89	*Piptatherum aequiglume* (Duthie ex Hook.f.) Rozhev.	Central Asia and China to NW India and Pakistan/CENTASIA.
90	*Piptatherum baluchistanicum* Freitag	East Afghanistan, Baluchistan Pakistan/ENDEM.

Table 2. (Cont'd).

S.No	Taxa	Distribution
91	*Piptatherum gracile* Mez	Tajikistan through Himalayas Pakistan, India, Nepal, China/WHIMAL.
92	*Piptatherum hilariae* Pazij	Asia-temperate, Central Asia, western Asia, and China, India, Pakistan/CENTASIA.
93	*Piptatherum laterale* (Munro ex Regel) Rozhev	Pakistan westward through Afghanistan to the pamirs/IRTURAN.
94	*Piptatherum munroi* (Stapf) Mez	Western Asia and China to Pakistan/WHIMAL.
95	*Poa aitchisonii* Boiss.	Western Asia: Iran, Afghanistan, NW Himalayas Pakistan/IRTURAN.
96	*Poa alpine* L.	Europe, North America, Mediterranean, N. Africa, Western Asia, Central Asia, Eastern Asia, Himalayas from Pakistan through India to Nepal/HOLARCT.
97	*Poa annua* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
98	*Poa attenuate* Trin.	Asia-temperate, China and Mongolia, NW Pakistan and India/CENTASIA.
99	*Poa bulbosa* L.	Europe, Africa, Asia-temperate, western Asia, Arabia, and China, Asia-tropical, Australasia, North America, southern South America/COSMO.
100	*Poa calliopsis* Litw. ex Ovcz.	Central Asia, China, Kashmir Himalayas/CENTASIA.
101	*Poa glauca subsp. Litwinowiana* (Ovcz.) Tzvelev	High Mountains in Central Asia, China, Tibet, Western Himalayas/CENTASIA.
102	*Poa infirma* Kunth	Europe, Africa north, Asia-temperate, Asia-tropical, Australasia, North America, Mexico, western South America/COSMO.
103	*Poa nemoralis* L.	Europe, N. Africa, Asia-temperate, western Asia, eastern Asia. Asia-tropical, Australasia, North America, South America/COSMO.
104	*Poa nepalensis* Wall. ex Duthie	China, eastern Asia, Himalayas India, Pakistan/WHIMAL.
105	*Poa pagophila* Bor	China and Himalayas/WHIMAL.
106	*Poa polycolea* Stapf	Afghanistan, China, Western Himalayas/WHIMAL.
107	*Poa pratensis* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
108	*Poa stapfiana* Bor	China and Western Himalayas/WHIMAL.
109	*Poa sterilis* M. Bieb.	Europe: eastern, Asia-temperate: Caucasus and western Asia, NW India and Pakistan/CENTASIA.
110	*Poa himalayana* Nees ex Steudel	China and western Himalayas/WHIMAL.
111	*Poa supine* Schrad.	Europe, Asia-temperate, China and Mongolia, NW Pakistan and India/EURASIA.
112	*Poa trivialis* L.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
113	*Poa versicolor subsp. Araratica* (Trautv.) Tzvelev	Europe, Asia-temperate, Caucasus, China, Mongolia, and eastern Asia, Himalayas/CENTASIA.
114	*Stipa himalaica* Rozhev.	China and Western Himalayas/WHIMAL.
115	*Trisetum clarkei* (Hook.f.) R. R. Stewart	China and Western Himalayas/WHIMAL.
116	*Trisetum spicatum* (L.) Richt.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.
117	*Vulpia myuros* (L.) C. C. Gmel.	Europe, Africa, Asia-temperate, Western Asia, Eastern Asia, Asia-tropical, Australasia, Pacific, North America, South America, Subantarctic islands/COSMO.

Codes: N- North, W- West, E- East, SE- Southeast; CIRCUMPOL- circumpolar element; COSMO- cosmopolitan element; ENDEM- endemic element; CENTASIA- central Asian element; HOLARCT- Holarctic;EURAS- Eurasiatic element; IRTURAN- Irano-Turanian element; MEDIT- Mediterranean element; WHIMAL- Western Himalayan element; PANTROP- pantropical; PALEOTROP- paleotropical.

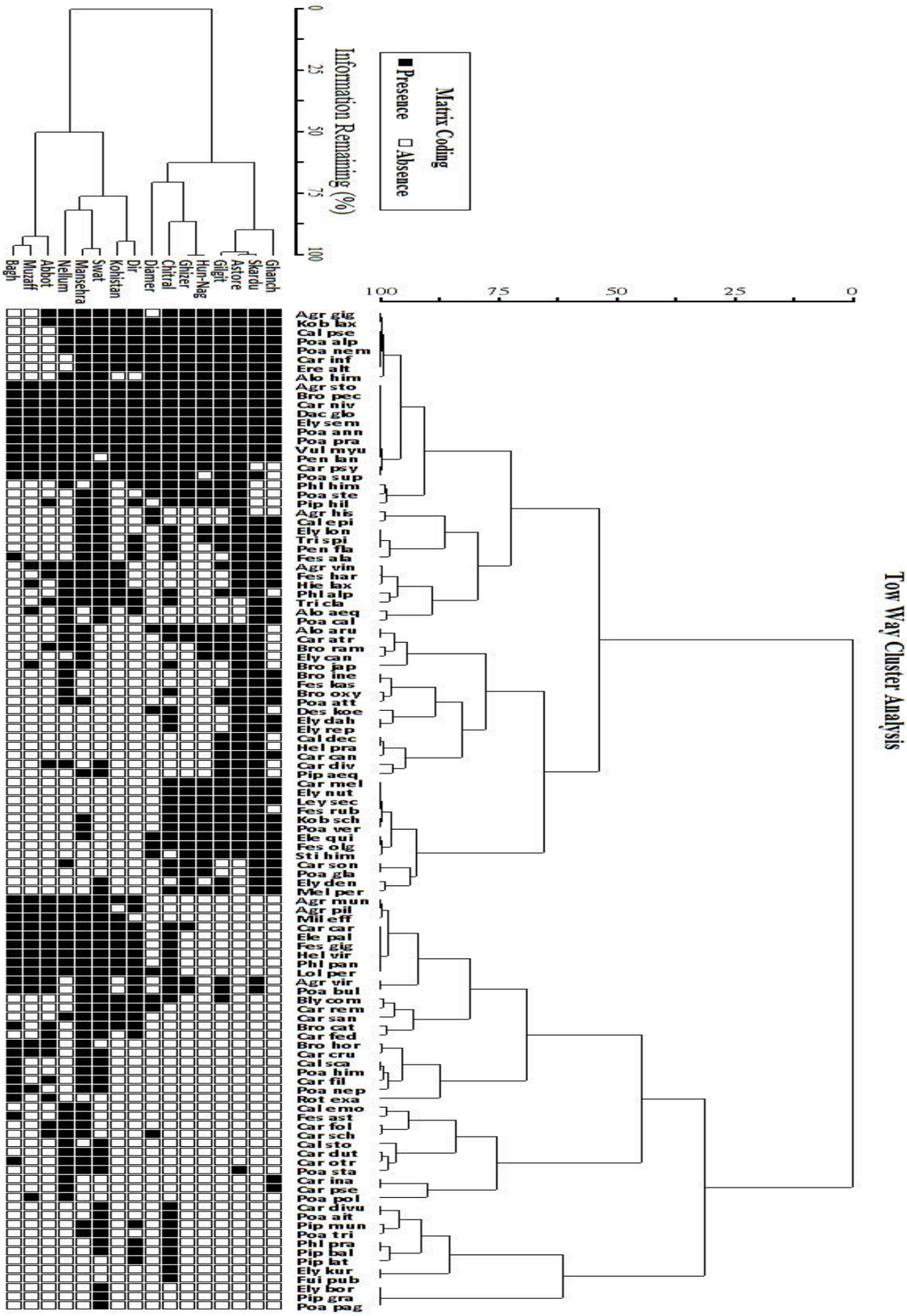

Fig. 4.Dendrogram of 114 species and 16 sites (OGU's), produced by TWCA through PC-ORD.

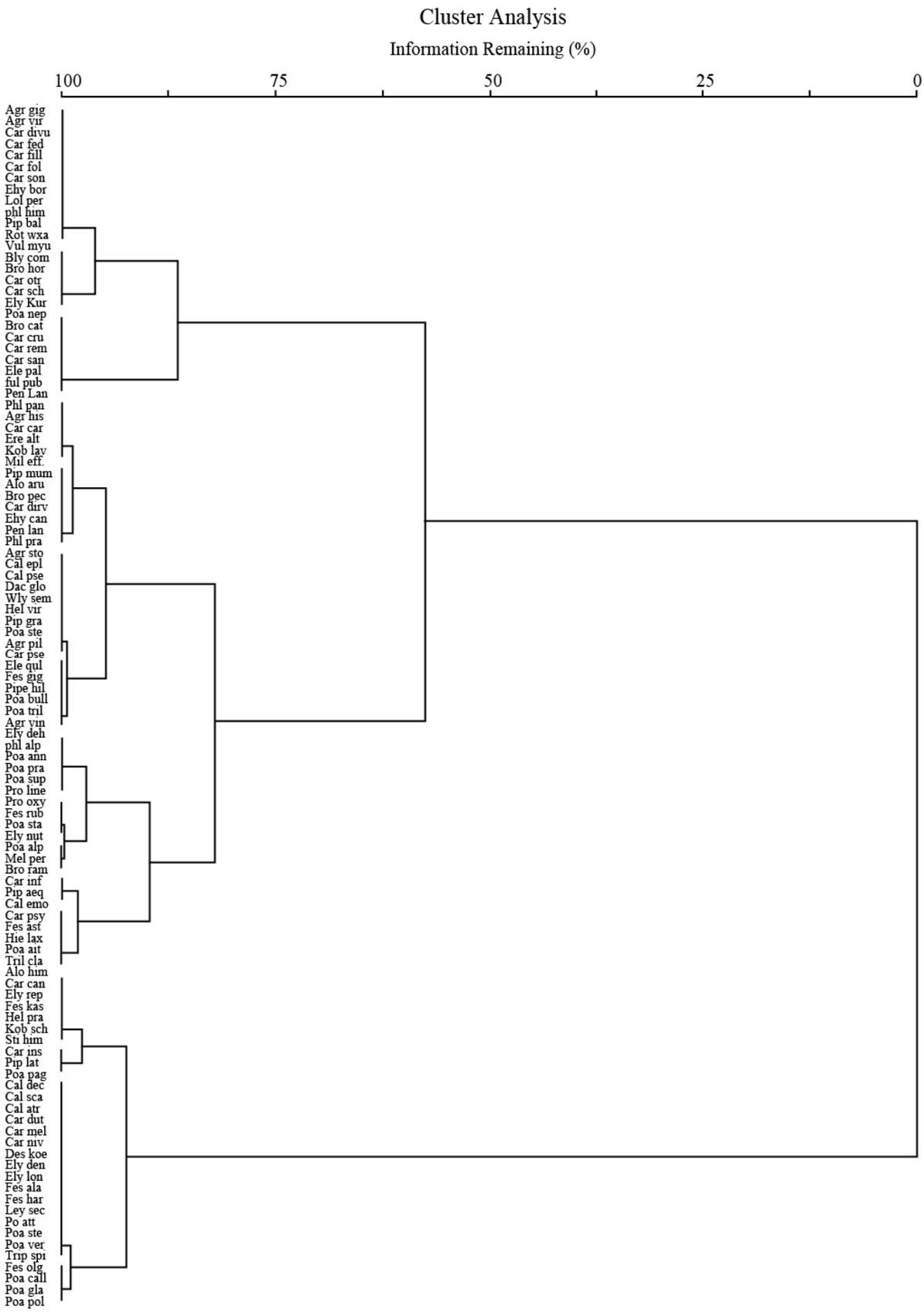

Fig. 5. Cluster dendrogram of species based on altitudinal distribution

Twoway cluster analysis based on presence/absence data of species: In the TWCA analysis based on the presence/absence data, 114 species in the data matrix are grouped into two large clusters i.e. Cluster 1 and Cluster 2 (Fig. 4). The dendrogram in (Fig. 4) shows very interesting results. The species are clearly grouped into two clusters corresponding to the upper northern and lower southern districts. Cluster 1 consists of 65 species that are found only in the upper eight northern and northeastern districts as well as the species with wider distribution in almost all districts. Cluster 2 consists of 46 species with distribution in the lower eight southern temperate districts. Cluster 1 further consists of 4 groups and cluster 2 contains 3 groups.

In group 1 there are 22 species out of which 8 species have distribution in all the 16 districts (Fig. 4), the remaining species have distribution in 8 or more districts. Most of these species are cosmopolitan in distribution and found at wider altitudinal ranges. Some of the weedy species also fall in this group e.g.,*Poaannua, Bromuspectinatus, Poapratensis*and*Vulpiamyuros* etc. These species favors open sunny, waste places and cultivated fields. The distribution range varies between 1000 to 3500 m. In the group 2 there are 13 species. Which are distributed in moist alpines or coniferous forests under storey, between 3000 and 3500m. These are distributed in Ghanche, Skardu, Astor, Swat and Mansehra. The 17 species in group 3 are primarily distributed in Skardu and Astor districts. These districts represent the northern most extension for these species, as the centre of diversity of these species lies in the northern India and Kashmir. These species are rare and found in high, dry arid alpines on dry slopes or on dry dunes in Deosai plateau. In group 4 there are 13 species with distribution in the upper 7 districts except Diamer. These species are found in dry snowy deserts and some are found among other grasses in alpine meadows. *Kobresiashoenoides* form large patches on dry dunes as well as on wet meadows in Deosai plains above 4000m, and contribute to the formation of peat soil. These *Kobresia*meadows are also found at similar altitudes in Alborzmountain Iran (Noroozi *et al.,* 2011) and Tibet China (Qiong *et al.,* 2011).

In group 5there are 23 species occupying almost all the lower districts. Most of these species prefer temperate forests and shady wet places, with frequent monsoon rains in the summer. The 11 species in group 6 occur only in the biodiversity rich temperate and alpine region of Swat and Mansehra districts. These species are part of the ground flora under the shade of conifer forests and hence prefer wet and shady places. This group is represented by 12 species, which are rare and having distribution in one or two districts. Some endemic species are also represented in this group.

Cluster analysis of species on the basis of altitude: The TWCA analysis of species based on altitude are summarized in the dendrogram (Fig. 5). The analysis divided the species into 4 large groups based on altitude, which further form small clusters, making a total of 16 distributional types within the altitudinal ranges of below 2000m to 5000m a.s.l. Species richness and composition varies with altitudinal gradient (Korner 2007; Nagy & Grabherr 2009; Shaheen *et al*., 2012; Khan *et al*., 2011). Because with increase in altitude temperature decreases and precipitation in the form of snow fall increases (Grytnes, 2000; Qiong *et al*., 2011) and hence species richness decreases and composition changes. It is apparent form the results (Fig. 5) that most of the species are distributed between 3000-4000m a.s.l. Our findings are in agreement with (Noroozi *et al*., 2008) who found that species richness is maximum between 3000 and 3600 m in Iranian Alpines.

In group A there are 27 species, with distribution ranges from below 2000m to 3000m. This group further contains 3 sub-groups. The first sub-group is distributed from below 2000m to 3000m, the second sub-group between 2000-3000m and the third sub-group from below 2000m to 2500m. These altitudinal belts are held by *Agrostisgigantea, A. viridis, Carexfedia, C. filicina, C. divulsa, C. foliosa, Elymusborianus, Phleumhimalaicum, Vulpiamyorus*etc. Ingroup B are included 31 species, which are distributed above 2000m and below 4000m. There are four small clusters present in this group. These species are primarily distributed in the temperate forests and extending into the alpine meadows. Common representatives of this group are *Agrostishissarica, Kobresialaxa, Milliumeffusum, Bromus japonicas* etc. Group C has a total of 22 species distributed between 2500m and 4500m above sea level. Further it is divided into 2 sub-clusters C1 and C2. In group D there are 33 species distributed between 3000 and 5000m. Most of these are strict alpine species with distribution in alpine meadows or nival zone. Genera like *Poa, Carex, Festuca*and*Calamagrostis* are dominant here.

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