PLANT SPECIES DIVERSITY AND ROLE OF SOIL NUTRIENTS IN THE SEMI-ARID TRACT OF DISTRICT BANNU KHYBER PAKHTUNKHWA PAKISTAN

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ABSTRACT
Communities are the result of species interactions for the resources. Plant species compete for the resources above and below the soil and ameliorate the environment for neighboring species. In this way superior competitors eliminate the inferior competitive species and affect the phytodiversity of an area. As a result those species sustain which are acclimatized to the prevailing environment. Hence, considering the relative influence of species interactions and an environment on the diversity, we expected variations in the diversity of plant species along the edaphic gradients. We investigated eastern, western and northern sites in the semi-arid area of District Bannu, Khyber Pakhtunkhwa, Pakistan, to identify the plant species diversity and its relation with the variation in the selected edaphic variables. We analyzed the soil samples of the three sites for the micro and macro-elements. We used quadrate method to collect the quantitative data of the plant species. Shanoon`s diversity index and similarities among the sites of the plant species was used to analyze the correlation between the diversity and the edaphic variables. Higher importance value index for tree species was computed as compared to shrubs and herbs. We have observed less diversity among the three sites in which western and northern sites have more similarities. We did not find a relationship in the edaphic variables for the macro-elements. However, few micro-elements have shown strong correlation with the diversity. We argue that less diversity may be the result of environmental filtering and anthropogenic activities prevailing in the area.

Keywords: Adaptation, disturbance, conservation, diversity, grazing.

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INTRODUCTION

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Current studies on the significance of neutral vs. deterministic processes (Hubbell, 2001; Morlon et al., 2009) in the species assemblages and their relative abundances within communities are important questions in ecology (McGill, 2010; Murrell, 2010). Neutral theory has successfully predicted that species trait differences are not the only factors involved in generating the observed pattern of diversity in nature (Chave, 2004). However, habitat and ecological filters select those species which possess a trait syndrome suitable for a given environment (Keddy, 1992; Diaz et al., 1998). Those species which are functionally dissimilar are usually excluded because they cannot cope with local environmental stress (Grime, 1973; Mayfield and Levine, 2010). For example, tall, fast growing species have strong competitive effect on local resources and act as a habitat filter by excluding less competitive species in productive meadows (Grime et al., 1997; Grime, 2006).

However, the strength and significance of competition varies along the gradients of environmental stress or resource availability (Greenlee and Callaway, 1996; Goldberg and Novoplansky, 1997). In plant communities, for instance, as the age of the community advances, competition and facilitation also changes among the species like the seedlings may use larger individuals as 'nurses', but compete with them when they become adults (Banuet and Verdú, 2008). As a result, the distribution of plant species at small spatial scale changes with the change in environmental conditions (Collins and Klahr, 1991).

To assess the generality of communities' structure, we surveyed the semi-arid zone in District Bannu Khyber Pakhtunkhwa, Pakistan to find the field evidence supporting the prediction that communities exhibit species diversity along edaphic gradients in an area which has not been explored until due to war against terrorism in the area. Therefore, the assessment of flora of a war effected region is an important to evaluate the vegetation in a given geographical area ecosystem (Pei, 1998; Hamilton, 2007). Species diversity assessments often provide indication of spatial and temporal changes of community structure (Swenson, 2011). For this purpose phytosociological survey is a valuable method for the assessment involving investigation of characteristics of plant communities using simple and rapidly employing field techniques (Rieley and Page, 1990).

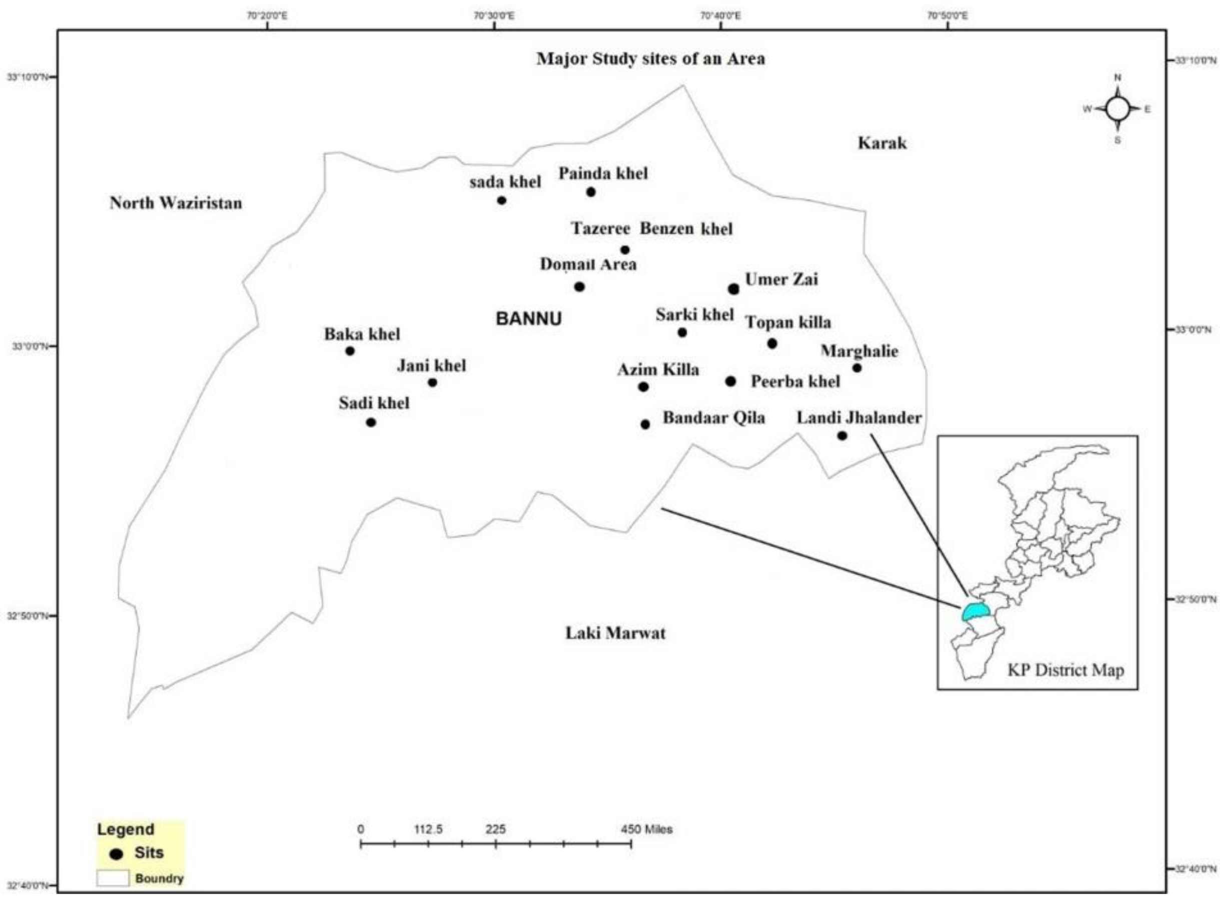
Considering the importance of floristic assessment in revealing the species interactions, we expect species variations and abundances along the edaphic gradients of the semi-arid zone. For this purpose, in present study, we assessed the diversity of plant species in the semi-arid region of District Bannu along edaphic factors (i.e. soil organic matter, Al, P, Ca, Mg, K, pH, cation exchange capacity of soil). We tried to answer the following questions: (1). How much diversity of plants is present in the stands of District Bannu? (2). What is the role of abiotic factors on the diversity of the stands in District Bannu? (3). How much is the similarity of vegetation in different stands of District Bannu?

MATERIALS AND METHODS

Study site

The present study of plant diversity in the semi-arid zone of District Bannu covers an area of about 1,227 Km^2. Bannu is the oldest and important District of Khyber Pakhtunkhwa, Pakistan. It is located in between 32.43° to 33.06° North latitude and from 70.22° to 70.57° East longitude. According to Kopppen (1948) climate classification, Bannu is located in BSh regions of the world. The average annual temperature is 23.6°C with highest in June on average at around 33.6°C and January is the coldest month with temperature averaging 11.7°C. The rainfall here averages 327 mm with least amount of rainfall occurs in November about 4 mm and most of the precipitation here falls in July, averaging 69 mm.

We classified the area into three stands on the basis of direction from the main city of the District Bannu. We surveyed many sites on the eastern side of District Bannu such as Landi Jhalander, Bandaar Killa, Azim Killa, Barmi Khel, Topen Killa, Umer Zai, Sirki Khel, Marghalie Peerba Khel and Oligie Mosa Khel (Hereafter Eastern Stand), Baka Khel, Sardi Khel and Jani Khel (Hereafter Western Stand) and Painda Khel, Sada Khel, Spark Waziran, Amal Khel, Nadar Bodin Khel, Domel area, Tazeree Benzen Khel, Saed Khel and Jhando Khel (Hereafter Northern Stand) [Map 1].



Map 1. Detailed location of Study Area in District Bannu, Khyber Pakhtunkhwa.

Sampling

We used quadrat method to study and analyze the dynamics of vegetation to collect the primary data for statistical analysis. We placed 10 random plots of 100 m × 100 m having rich flora and geography of the area. We sampled those species that have DBH (diameter of breast height) ≥ 1 cm.

Soil Analysis

We collected the soil samples from 0-6 cm depth at 3 multiple of 3 different sites for elemental and physio-chemical analysis (Bao, 1999; Collison, 1977). We examined the soil texture using Hydrometer method (Bouyoucos, 1936) and textural classes with the help of textural triangle (Brady, 1999). We used standard wet burning method (Rayan et al., 1997) to determine the soil organic matter by oxidation with potassium dichromate in sulphuric acid medium. We used Kjeldahl method (Bremner and Mulvaney, 1982) to determine the total

Nitrogen. Similarly we used Olsen and Sommers (1982) and flame emission spectroscopy (Rhoades, 1982) methods to observe total Phosphorus and Potassium content of the soil, respectively. We measured the soil pH in 1:5 soil water suspensions with a pH meter (Jackson, 1962). We analysed the electrical conductivity of the soil in 1: 5 soil water interruptions with EC meter.

Data Analysis

Quantitative Analysis

Phytosociological survey, an important tool of ecology for vegetation assessment was conducted in 3 representative designated sites. We calculated the density, cover and frequency of each species following Cain et al.(1956) and Qadir and Shetvy (1986). Later on we also calculated Importance Value Index (I. V. I.) for each species in each sample using following formula:

I.V. I = Relevant Cover + Relative Frequency + Relative Density

We classified the sampled vegetation into different plant communities on the basis of Importance Value Index (IVI.). We named each community with the first three of the species having highest Importance Value Index irrespective of its habit (Hussain, 1989). However, the community share the names of two or more species when they closely approach each other in order of Importance Value. The name of the species with highest I.V appeared first and subsequently other dominant species.

Diversity Analysis

We used Shanoon's index (H) to $E_H = H/Hmax = H/InS$ to characterize species diversity in a community. The index accounts for abundance and evenness of the species present in the community. In this case the proportion of species i relative to the total number of species (p_i) is multiplied with the natural logarithm of this proportion (lnp_i). The resulting product is summed across species, and multiplied by -1:

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

Shannon's equitability (E_H) can be calculated by dividing H by H_{max} (here H_{max} = InS). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

We also tested whether the communities have similar composition or different from one another. We used Bray-Crutis method of dissimilarity index which is limited between 0 and 1, where 0 means that the two communities have the same composition or species are present in both communities, and 1 means that the species composition in two communities is different or both communities do not share any species (Bloom, 1981). Bray-Crutis method is one of the good methods of calculating the dissimilarity among the sites or different communities (Faith et al., 1987). It is also known as Steinhaus, Czekanowski and Sørensen index (R Documentation Vegdist "Vegan Package"). First we calculated dissimilarity and then subtracted from 1 to calculate the similarity. To calculate the similarity (Bray-Crutis) between the three different communities we used the 'vegan' package (Oksanen et al., 2011) in the R environment (Anon., 2012). We clustered those communities that are more similar using an agglomerative hierarchical clustering algorithm.

RESULTS

Phytosociology

Eastern Stand (Calligonum- Prosopis-Tamarix Community)

In general we found that trees and shrubs are the dominant plant of this stand based on high IVI values. However, Calligonum polygonoides L. was the dominant shrub among the community of this stand. Among the shrubs we observed Calligonum polygonoides L. with highest (87.4) IVI value followed by Periploca aphylla L. (52.03), Tamarix dioica Roxb.ex Roth (44.85), Rhazya stricta Decne. (44.18), Cistanche tubulosa (Schrenk) Hook (37.89) and Echinops echinatus Roxb. (33.63). While among the trees Prosopis cineraria (Linn.) Druce had the high IVI value of (77.55) followed by Tamarix aphylla (L.) Karst (62.44), Zizyphus jujuba Mill (61.20), Acacia nilotica ssp. astringens (Schumach & Thonn.) (56.19), and Cappris decidua (Forssk.) Edgew (42.62). However we also observed herbaceous plants with comparatively less IVI values in stand 1. We found Cymbopogon distense (Nees ex Steud.) Wats. with IVI value (32.96) followed by Chenrus cilairus L. (19.72, Cynodon dactylon (Linn.) Pers (18.5) and Astragalus scorpiurus Bunge (16.58) (Table-1).

Western Stand (Prosopis- Tamarix-Acacia Community)

Except only one shrub, most of the trees were dominant in the whole community of this stand. Among the trees, we found Tamarix aphylla (L.) Kart with high IVI value of (81.17) followed by Acacia nilotica ssp. stringenas (Schumach & Thonn.) with (76.60), Acacia modesta Wall with (61.42), Ziziphus jujuba Mill with (55.29) and Prosopis cineraria (Linn.) Druce with (25.50). Among the shrubs we observed Prosopis juliflora Swartz as the dominant plant in this stand with (103.61) IVI value followed by Aerva javanica (Burm. f.) Juss. ex Schult with (51.14), Calotropis procera (Willd) R. Br. with (47.96) and Rhazya stricta Decne. (41.65). Among the herbs Alhagi maurorum had the high IVI value with (52.15) followed by Cynodon dactylon Decne. with (50.7), Chenopodium murale L. (43.22), Polypogon nonspeliensis (L.) Desf with (41.31), Amaranthus viridus L. (39.14) and Achyranthes aspera L. (38.07) (Table-2).

Northern Stand (Prosopis- Tamarix-Phoenix Community)

We observed that northern stand has also the prevalence of trees and shrubs. Among the trees we found Tamarix aphylla (L.) Kart as the dominant plant with high (66.96) importance values followed by Prosopis cineraria (Linn.) Druce with (57. 26), Phoenix dactylifera L. with (52.55), Ziziphus jujube Mill with (43.64), Acacia nilotica ssp. astringens (Schumach & Thonn.) with (41.72) and Acacia modesta Wall with (37.87). Among the shrubs Prosopis juliflora Swartz was the dominant plant with high importance value of (69.22) followed by Tamarix dioica Roxb.ex Roth with (44.81), Rhazya stricta Decne.with (34.81) and Aerva javanica (Burm. f.) Juss. ex Schult with (32.05). IVI values of herbaceous plants were generally less than trees and shrubs. Among the herbs Cymobopogon distans (Nees ex Steud.) Wats. was the dominant with importance value (31.66) followed by Cynodon dactylon Decne. with (24.57), Cenchrus ciliaris L. with (20.66) and Malcolmia africana (L.) R.Br (20.37) (Table-3).

Diversity and Similarity

We observed 52, 85 and 62 plant species in eastern, western and northern stands respectively. Species diversity index was 3.814, 4.083 and 3.74 in eastern, western and northern stands respectively (Table-4). Most of the edaphic variables showed non-significant relation with the diversity. However, Fe, Ca, Cd, Mn have positive and Zn, Ni showed negative correlation with the diversity in all the three stands (Table-5).We found high similarity of plant species in western and northern stands than eastern (Figure 1).

DISCUSSION

The present study revealed the importance of conservation practices and provided a baseline data of this ecologically important area. Edaphic factors showed weak role to ameliorate the environment and effect interactions among the plants for the soil resources. We argued that less diversity is the result of human involvement in the area and disturbances due to grazing and land utilization practices. Environmental adaptations of the plants are the important characteristics for the establishment of species and prevalence in the area.

Phytosociological survey

In general semi-arid climate represent scrubby vegetation in which shrubs and herbs are the dominant habits of the plants. However, the high relative density of few trees in our study may be due to their allelopatheic behaviour and better adaptations which leads them as the dominant plants of the area. For example the dropped leaves of Tamarix plant have high contents of salts which make the soil saline around their vicinity preventing the seed germination of other plants (Morris et al., 2009; Natale et al., 2010). Similarly Prosopis and Ziziphus species have also well adapted roots for the absorption of water and minerals in water stress conditions and thick barks to withstand the extreme environment (Elfadl & Luukkanen, 2003; Arndt et al., 2001).

We also observed the presence of few dominant shrubs in all the stands. For example Calligonum and Rhazya species are usually non-palatable due to the presence of certain chemicals which give bitter taste and un-pleasant smell for the animals (Samejo et al., 2013; Quets et al., 2014). The presence of odour volatile oils in Rhazya also reduces their fuel consumption among the people of the area. Moreover, the vegetative propagation in Calligonum also help in an increasing the density of the plant (Samejo et al., 2013; Quets et al., 2014).

We have observed that constant and continuous grazing in the area is also responsible for the less diversity of plant species. The livestock totally depend on the grasses and wild herbs due to less cultivation of fodder. Due to poverty and less ownership of the lands, the local people are confined to cultivate only a few crop plants only for themselves. Therefore, the absence of cultivated fodder confined the livestock to graze wild herbs. Irregular and uncontrolled grazing of the livestock also has laid negative impact on the diversity of the plants.

Diversity and Similarity

We observed less diversity and high similarity among the stands. Diversity among the sites and within the stands may be related to vulnerability of the plants to the people and environmental disturbances. Generally, habitat and land use drive non-random changes in diversity (Mace et al., 2003) as the disturbance reduces the impact of interspecific competition through local extinction of disturbance-vulnerable species and change local habitat conditions, which may lead to environmental filtering of species in community assembly with increasing disturbance (Winter et al., 2013).

Similarity among the stands may be due to the general climate of the semi-arid environment is harsh which is not suitable for the plants and only those plants can survive best which are best adapted with the environment (Luzuriaga et al., 2012; Keddy,1992; Diaz et al.,1998) resulting a positive relationship between species traits (Shipley et al., 2006). Our findings also revealed the higher density of those plants which are good adapted with the environment. For example Tamarix has thick bark and spiny leaves which reduce the transpiration rate of the plants. Similarly Prosopis and Acacia have also thick bark, deep roots and small leaves which are the suitable characteristics to the semi-arid environment (Natale et al., 2010; Arndt et al., 2001).

Diversity along the edaphic variables

We did not find significant correlation of the plant diversity with the edaphic abiotic variables in all the three studied sites. Our results explained that edaphic factors are not as influential in the studied stands. However little effect of the micro-elements on the vegetation may be due the edaphic elemental spatial heterogeneity. Spatial heterogeneity influences diversity by increasing the number of habitats types and affecting ecological processes such as dispersal and competition (Dufour et al., 2006) through the spatial configuration of habitats. Heterogenic microenvironment provides equal opportunity to every species for the growth and development. (Lundholm & Larson, 2003; Pausas et al., 2003; Leigh et al., 2004; Dufour et al., 2006). For example, in South Africa Thuiller et al., (2006) showed that topographic heterogeneity could improve plant richness both by increasing the number of niches in space and by keeping the number of niches relatively stable in time.

CONCLUSION

We observed that trees and shrubs are the dominant vegetative habit in the studied area. Semi-arid zone of District Bannu has a higher diversity of plants and is not related to the edaphic factors of the area. We also found high similarity in the plant species of the studied area. Future studies could explore the plant species co-occurrence, phylogenetic and functional characteristics of this zone to determine the relation of plants and environment aspects of plant species diversity.

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Table-1. Plant species of the Eastern stand from the semi-arid zone of District Bannu, KP, Pakistan.

S.No	Name of plant	Family	IVI
1	Acacia nilotica (L.) Wild. ex Delile	Mimosaceae	56.19
2	Cappris decidua (Frossk.) Edgew.	Cappridaceae	42.62
3	Prosopis cineraria L.	Mimosaceae	77.55
4	Tamarix aphylla (L.) Karst.	Tamaricaceae	62.44
5	Ziziphus jujuba Mill.	Rhamnaceae	61.2
6	Calligonum polygonoides L.	Polygonaceae	87.4
7	Periploca aphylla Decne.	Asclepiadaceae	52.03
8	Tamarix dioica Roxb. ex Roth.	Tamaricaceae	44.85
9	Rhazya stricta Decne.	Apocynaceae	44.18
10	Echinops echinatus L.	Asteraceae	33.63
11	Cistanche tubulosa (Shehenk.) Hook.f.	Orobancheaceae	37.89
12	Arnebia hispidissima (Lehm.) A. DC.	Boraginaceae	13.12
13	Astragalus scorpiurus Bunge.	Papilionaceae	16.58
14	Boerhavia procumbens Banks ex Roxb.	Nyctaginaceae	14.23
15	Cenchrus ciliaris L.	Poaceae	19.72
16	Chenopodium album L.	Chenopodiaceae	15.38
17	Convolvulus arvensis L.	Convolvulaceae	11.8
18	Cymbopogon distanse Schutt.	Poaceae	32.96
19	Cynodon dactylon (L.) Pers.	Poaceae	18.5
20	Euphobia dracunculoides Lam.	Euphorbiaceae	11.37
21	Farsetia jacquemontii (Hook. f & Toms.) Jafri	Brassicaceae	8.61
22	Heliotropium europaeum (F. & M.) Kazmi	Boraginaceae	8.87
23	Hypecoum pendulum L.	Papaveraceae	9.26
24	Launaea procumbens Pravin Kawale.	Asteraceae	12.61
25	Melilotus indica (L.) All.	Papilionaceae	9.68
26	Oligomeris linifolia (Vahl.) Macbride	Resedaceae	6.29
27	Plantago lanceolata L.	Plantaginaceae	9.19
28	Plantago ovata Frossk.	Plantaginaceae	7.98
29	Psammogeton biternatum Edgew.	Apiaceae	9.32
30	Rostraria cristata L.	Poaceae	14.13

31	Rumex dentatus (Meisn.) Rech.f.	Polygonaceae	9.85
32	Silene vulgaris (Moench) Garcke.	Caryophyllaceae	12.48
33	Sisymbrium irio L	Brassicaceae	12.14
34	Trigonella crassipes Boiss.	Papilionaceae	15.46
35	Alhagi maurorum Medic.	Papilionaceae	24.94
36	Amaranthus viridis L.	Amaranthaceae	21.92
37	Aristida cynantha L.	Poaceae	28.57
38	Carthamus persicus Willd.	Asteraceae	20.26
39	Chrozophora plicata (Vahl) A. Juss. ex Spreng.	Euphorbiaceae	18.51
40	Citrullus colocynthis (L.) Shred.	Cucurbitaceae	17.61
41	Cyperus rotundus L.	Cyperaceae	18.87
42	Eragrostis pilosa (L.)P. Beauv.	Poaceae	26.72
43	Eragrostis minor Host.	Poaceae	20.98
44	Euphorbia prostrata Ait.	Euphorbiaceae	18.22
45	Fagonia indica L.	Zygophyllaceae	21.92
46	Plantago ovata Frossk.	Plantaginaceae	14.2
47	Portulaca oleraceae L	Aizoaceae	13.97
48	Cenchrus bifolrus Roxb.	Poaceae	73.4
49	Aristida adscensionis L.	Poaceae	38.16
50	Dichanthium annulatum (Forssk.) Stapf	Poaceae	38.91
51	Launaea angustifolia (Desf.) Kuntze	Asteraceae	27.35
52	Malva neglecta Wallr.	Malvaceae	38.76

Table-2. Plant species of the Western stand from the semi-arid zone of District Bannu, KP, Pakistan.

S.No	Name of Plants	Family	IVI
1	Acacia modesta Wall.	Mimosaceae	61.42
2	Acacia nilotica (L.) Wild.ex Delile	Mimosaceae	76.6
3	Tamarix aphylla (L.) Karst	Tamariaceae	81.17
4	Ziziphus jujuba Mill.	Rhamnaceae	55.29
5	Prosopis cineraria L.	Mimosaceae	25.5
6	Aerva javanica (Burm. f) Juss.	Amaranthaceae	51.14
7	Calotropis procera (Willd.) R. Br.	Capparidaceae	47.96
8	Prosopis juliflora Swartz.	Mimosaceae	103.61
9	Rhazya stricta Decne.	Apocynaceae	41.65
10	Withania coagulans Dunal.	Solanaceae	55.65
11	Alopecurus nepalensis Trin.ex Steud.	Poaceae	5.45
12	Anagallis arvensis L.	Primulaceae	9.03
13	Atriplex stocksii Boiss	Chenopodiaceae	6.50
14	Calendula officinalis L.	Asteraceae	10.04
15	Carduus argentatus L.	Asteraceae	5.41
16	Cirsium arvense (L.) Scop.	Asteraceae	6.55
17	Cymbopogon distanse Schutt.	Poaceae	8.06
18	Datura alba Nees.	Solanaceae	6.01
19	Dinebra retroflexa (Vahl) Panzer.	Poaceae	3.43
20	Echinochloa crus-galli (L.) P. Beauv.	Poaceae	4.37
21	Euphorbia helioscopia L.	Euphorbiaceae	15.24
22	Euphorbia prostrata Ait.	Euphorbiaceae	8.09
23	Fagonia indica L.	Zygophyllaceae	8.02
24	Filago pyramidata L.	Asteraceae	3.39
25	Fumeria indica Hausskn.	Fumariaceae	9.09
26	Heliotropium crispum Desf.	Boraginaceae	3.83
27	Lactuca serriola L.	Asteraceae	5.29
28	Lathyrus aphaca L.	Papilionaceae	3.89
29	Launaea procumbens Pravin Kawale	Asteraceae	3.18
30	Leptochloa panacea Retz	Poaceae	4.40
31	Malva neglecta Wallr.	Malvaceae	3.85
32	Medicago polymorpha L.	Papilionaceae	6.93
33	Melilotus alba Desr.	Papilionaceae	3.52
34	Melilotus indica (L.) All.	Papilionaceae	5.41
35	Neslia apiculata Fisch.	Brassicaceae	3.43
36	Nicotiana plumbaginifolia Viv.	Solanaceae	4.01
37	Oxalis corniculata L.	Oxalidaceae	4.69
38	Phalaris minor Retz.	Poaceae	4.60
39	Plantago lanceolata L.	Plantaginaceae	7.27
40	Poa annua L.	Poaceae	12.95

41	Poa botryoides (Trin. ex Griseb.) Kom.	Poaceae	5.18
42	Polygonum plebejum R.Br	Polygonaceae	4.70
43	Ranunculus sceleratus L.	Ranunculaceae	3.79
44	Rumex dentatus (Meisn.) Rech.f.	Polygonaceae	4.12
45	Polypogon monspeliensis (L.) Desf.	Poaceae	9.40
46	Sisymbrium irio L	Brassicaceae	8.42
47	Sonchus asper (L.) Hill.	Asteraceae	7.90
48	Solanum nigrum L.	Solanaceae	3.80
49	Taraxacum officinale F.H. Wiggers	Asteraceae	8.97
50	Torilis nodosa (L.) Gaertn.	Apiaceae	5.90
51	Trigonella crassipes Boiss.	Papilionaceae	7.32
52	Verbena officinalis L.	Verbenaceae	5.05
53	Xanthium strumarium L.	Asteraceae	6.60
54	Alhagi maurorum Medic.	Papilionaceae	52.15
55	Aristida cyanantha Nees ex Steud.	Poaceae	22.75
56	Cenchrus ciliaris L.	Poaceae	29.83
57	Conyza bonariensis (L.) Cronquist	Asteraceae	26.21
58	Cyperus rotundus L.	Cyperaceae	30.39
59	Fagonia cretica L.	Zygophyllaceae	27.85
60	Heliotropium strigosum Willd.	Boraginaceae	18.68
61	Achyranthes aspera L.	Amaranthaceae	38.07
62	Amaranthus viridis L.	Amaranthaceae	39.21
63	Boerhavia procumbens Banks ex Roxb.	Nyctaginaceae	21.19
64	Chenopodium murale L.	Chenopodiaceae	43.22
65	Corchorus depressus L.	Tiliaceae	17.06
66	Solanum surattense Burm.f.	Solanaceae	20.70
67	Tribulus terrestris L.	Zygophyllaceae	20.31
68	Avena fatua L.	Poaceae	23.97
69	Convolvulus arvensis L.	Convolvulaceae	29.32
70	Cynodon dactylon (L.) Pers.	Poaceae	45.37
71	Dichanthium annulatum Forssk.	Poaceae	39.17
72	Setaria pumila (Poir.) Roem.	Poaceae	22.40

Table-3. Plant species of the Northern stand from the semi-arid zone of District Bannu, Khyber Pakhtunkhwa, Pakistan.

S.No	Name of plants	Family	IVI
1	Acacia modesta Wall.	Mimosaceae	37.87
2	Acacia nilotica (L.) Wild.ex Delile	Mimosaceae	41.72
3	Phoenix dactylifera L.	Araceae	52.55
4	Prosopis cineraria L.	Mimosaceae	57.26
5	Tamarix aphylla (L.) Karst	Tamaricaceae	66.96
6	Ziziphus jujube Mill.	Rhamnaceae	43.64
7	Aerva javanica (Burm.f.) Juss.	Amaranthaceae	32.05
8	Calotropis procera (Willd.) R. Br.	Asclepiadaceae	31.74
9	Cistanche tubulosa (Shehenk.)	Orobanchaceae	28.77
10	Prosopis juliflora Swartz.	Mimosaceae	69.22
11	Rhazya stricta Decne.	Apocynaceae	34.84
12	Tamarix dioica Roxb. ex Roth.	Tamaricaceae	44.81
13	Vitus negundo L.	Vitaceae	24.24
14	Withania coagulans Dunal.	Solanaceae	34.31
15	Anagallis arvensis L.	Primulaceae	14.08
16	Avena fatua L.	Poaceae	10.24
17	Calendula officinalis L.	Asteraceae	10.64
18	Carthamus persicus Willd.	Asteraceae	11.98
19	Cenchrus ciliaris L.	Poaceae	20.66
22	Cymbopogon distanse Schutt.	Poaceae	31.66
24	Datura alba Nees.	Solanaceae	13.33
25	Euphorbia helioscopia L.	Euphorbiaceae	9.35
26	Heliotropium europaeum (F. & M.) Kazmi	Boraginaceae	10.83
27	Malcolmia Africana (L.) R.Br.	Malvaceae	20.37
28	Onosma chitralicum I.M.Johnston	Boraginaceae	9.12
29	Pegnum harmala L.	Zygophyllaceae	16.26
30	Polygonum plebejum R.Br	Polygonaceae	8.83
31	Rumex dentatus (Meisn.) Rech.f.	Polygonaceae	13.15
32	Sisymbrium irio L	Brassicaceae	14.43
33	Sonchus asper (L.) Hill.	Asteraceae	12.74
34	Spergula fallax (Lowe) E.H.L. Krause	Caryophyllaceae	5.15
35	Taraxacum officinale F.H. Wiggers	Asteraceae	14.33
36	Alhagi maurorum Medic.	Papilionaceae	25.33
37	Avena fatua L.	Poaceae	14.16
38	Bromus pectinatus Thunb.	Poaceae	29.4
40	Cenchrus biflorus Roxb.	Poaceae	23.33
42	Cyperus rotundus L.	Cyperaceae	12.86
43	Eleusine indica (L.) Gaertn.	Poaceae	31.32
44	Fagonia cretica L.	Zygophyllaceae	11.73

46	Poa annua L.	Poaceae	23.48
49	Achyranthes aspera L.	Amaranthaceae	34.47
50	Amaranthus viridis L.	Amaranthaceae	28.04
51	Boerhavia procumbens Banks ex Roxb.	Nyctaginaceae	28.47
52	Bromus pectinatus Tumb.	Poaceae	40.61
53	Chenopodium murale L.	Chenopodiaceae	29.63
54	Citrullus colocynthis (L.) Shred.	Cucurbitaceae	34.53
57	Solanum surattense Burm.f.	Solanaceae	27.42
58	Aristida adscensionis L.	Poaceae	33.85
59	Chenopodium album L.	Chenopodiaceae	51.52
60	Convolvulus arvensis L.	Convolvulaceae	34.17
61	Cynodon dactylon (L.) Pers.	Poaceae	42.27
62	Dichanthium annulatum Forssk.	Poaceae	32.5

Table-4. Plant species richness and diversity of the three sites in semi-arid zone of District Bannu, KP Pakistan.

Sites	Species richness	Shanoon's Diversity index
Eastern	52	3.81
Western	85	4.08
Northern	62	3.74

Table-5. Correlation of plant species diversity index of the three sites along edaphic variables in the semi-arid zone of District Bannu, KP, Pakistan. Significant values at α = 0.05 are in bold. PH = Power of Hydrogen, EC = Electric conductance, OM = Organic matter, N = Nitrogen, P = Phosphorus, K = Potassium, S = Sulphur, Si = Silicon, Fe = Ferrous, Cu = Copper, Zn = Zinc, Ca = Calcium, Mg = Magnesium, Pb = Lead, Cd = Cadmium, Ni = Nickle, Cr = Chromium, Mn = Manganese.

Edaphic variables	P values	Co-efficient
PH	0.29	-0.5
EC in (dScm-1)	0.81	0.5
OM in %	0.6	0.5
N	0.49	-0.5
P	0.33	-0.5
K	0.34	-0.5
S	0.77	0.5
Si	0.24	-0.5
Fe	0.01	1
Cu	0.01	1
Zn	0.01	-0.5
Ca	0.01	1
Mg	0.14	0.5
Pb	0.13	-1
Cd	0.03	0.5
Ni	0.01	-1
Cr	0.32	-0.5
Mn	0.01	1

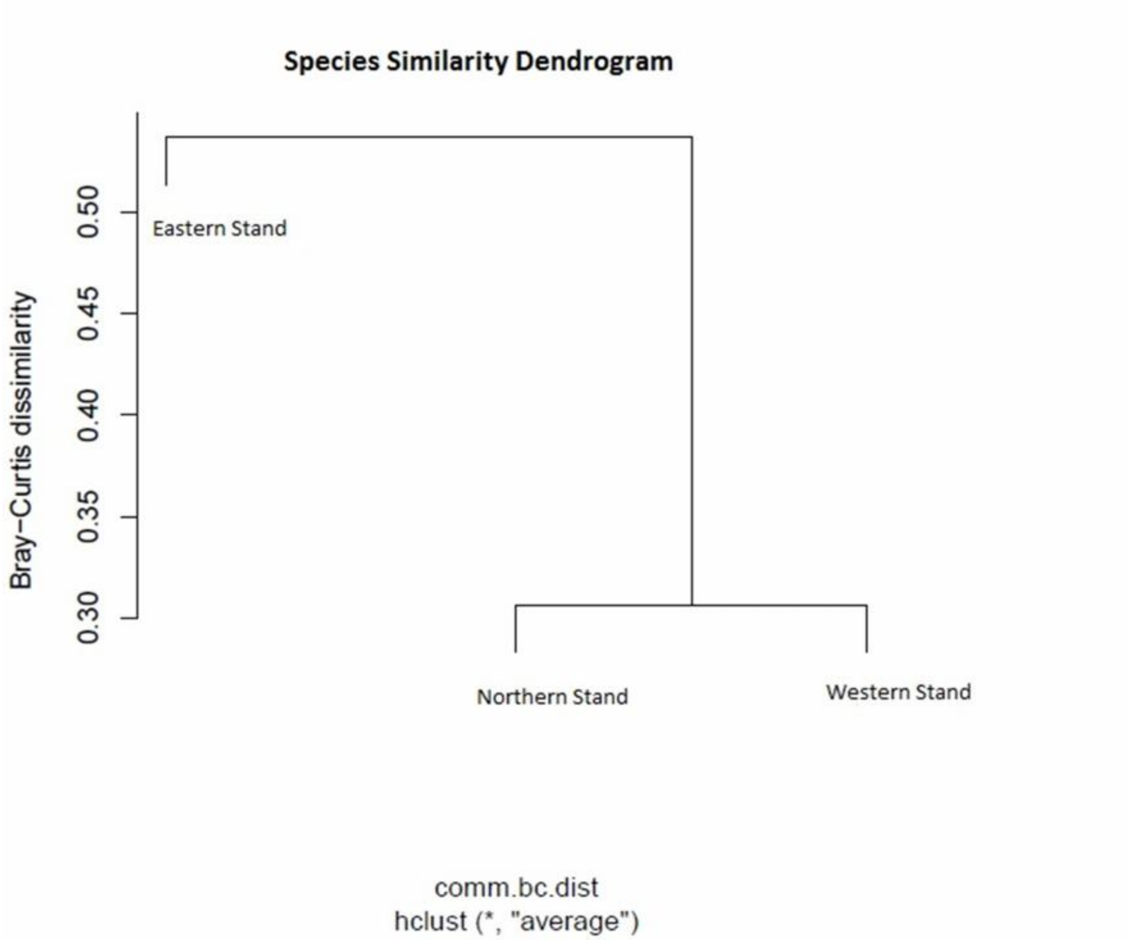

Fig. 1. The species similarity dendrogram among the stands in the semi-arid zone of District Bannu, KP, Pakistan.

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