PHYTODIVERSITY OF PIEDMONT AND ALLUVIAL REGIONS OF KOHE SULEMAN MOUNTAIN RANGE, DERA GHAZI KHAN, PUNJAB PAKISTAN WITH EMPHASIS ON THE ALTITUDINAL GRADIENT

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Abstract-This study assessed the phytodiversity distribution pattern and community composition with respect to the altitudinal gradient in three vegetation zones, like the riparian (30°03′22″ N, 70°64′44″ E), piedmont zone (29°54′00″ N, 69°58′00″ E) and upper rocky slopes (29°54′00″ N, 69°58′00″ E) of the Kohe Suleman Mountain range of district Dera Ghazi Khan, Pakistan with 104 to 1972 m above sea level (a.s.l) range of altitude. During the field surveys from the three sites, a total of 40 stands were employed for vegetation analysis using the normal cluster analysis (NCA) and the presence or absence of data were taken as indicators to classify and ordinate both the sites and species. Spearman's rank correlation coefficient (SRCC) was used to assess the relationship between environmental factors and species distribution. Results of the normal cluster analysis displayed overall three vegetation groups from the studied sites including *Chloris barbata-Eragrostis* minor community (group A), *Nerium oleander-Leptadenia pyrotechnica* community (group B) and *Bothriosperum tenellum* - *Acacia jacquemontii* community (group c) which were clearly separated along the first two axes of the DCA. Results of the Spearman's rank correlation coefficient indicated that the species richness and diversity (SR = 19.70$\pm$3.38, 14.30$\pm$1.97, 9.30$\pm$1.316; *F & P* = 54.92***) were decreased with respect to elevation (*r* =-0.712***) and a highly negative significant values of soil anions and cations with axis II confirmed the decline of nutrients with altitudinal gradients. It could be concluded that the distribution patterns of the species are strongly associated with elevation, concomitant variations in climatic regime as well as the edaphic factors of the region.

Index Terms- Altitudinal gradient, Dera Ghazi Khan, Koh-Suleman Mountain, phytodiversity, species distribution, vegetation zone

I. INTRODUCTION

In the dry elevated subtropical mountains throughout the arid zones of the world, wildlife and the valuable natural resources are quickly depleting (Nisar et al., 2013) due to the lack of planning and deficiency of information regarding conservation of wild germ plasm and continuous poor management practices for the use of land and natural resources. That's why; various ecologists are interested to address this issue in terms of general lack of knowledge of the values of the natural resources and the impacts of various kinds of land-uses practices upon other resources of any region (Arshad et al., 2008). Existing patterns of using natural resources are unsatisfactory; that contributes to the destruction of natural biodiversity (Choudhary & Nama, 2014). In most of the areas, species biodiversity has gone beyond the point of repair and there is a dire need to formulate ecological principals to encounter anthropogenic activities in the high elevated mountainous arid zones and developing guidelines based on such principles (Muhammad et al., 2013; Nisar et al., 2013). Such ecological strategies have a significant importance in shaping the paramount possible sustained benefits for mankind and to maintain the potential of renewable natural resources.

Diverse plant species and communities occurring in dry arid mountainous regions undergo considerably changes and resulting in altering the ecosystem functioning. The Suleiman Mountains range a part of Pakistan possesses an unusually rich flora because this part of country remained undisturbed by man for a long period; this enabled many species to survive and to evolve. In this area, there is a great variation in the different types of flora even at short distances. In mountainous forests different factors play important role in the distribution and composition of plant communities e.g. altitude and closely linked edaphic and climatic factors (Bhattarai et al., 2014; Khan et al., 2011; Shaheen et al., 2011; Wazir et al., 2008), topographic heterogeneity (Gulshan et al., 2014), soil chemistry (Dasti et al., 2010; Enright et al., 2005; Khan et al., 2011) competition between different species for soil nutrients, forest productivity (Hashim & Dasti, 2019), soil texture (Dasti et al., 2010; Saima et al., 2018) and availability of light (Kharkwal et al., 2005; Urooj et al., 2015). The combination of these factors determines the conditions for the growth and thus the distribution of species. Among these factors, altitude had overriding importance in determining the species diversity, richness, and distribution (Gulshan et al., 2014; Zhang et al., 2016). Altitude also influences the availability of soil nutrients and water resources (Noor & Khatoon, 2013; Shafiq et al., 2021) through redistribution of run-off. Dip and scarp and again concave and convex landscape often differ in moisture regime and consequently the overall flora. The accumulation of run-off takes place at various scales from small depression to large wades (run-on). Thus, niches and habitats of various kinds and sizes are formed which determine the structure and composition of vegetation (Dasti et al., 2010).

Ecologists are trying to understand the complex variations in species along with the elevation gradient in dry arid mountainous zones using statistical techniques to reduce the complexity of the field data set (Bhattarai et al., 2014). The use of multivariate techniques such as gradient analysis has been rare to be applied to the vegetation data in general (Bibi et al., 2020; Saima et al., 2018; Urooj et al., 2015). Much of research work has been conducted to explore the variation in species richness and available soluble soil nutrients (anions and cations) concentrations along with the elevation gradients using various numerical techniques (Arshad et al., 2008; Bhattarai et al., 2014; Devlal & Sharma, 2008; Gairola et al., 2009; Hamid & Raina, 2019; Karami et al., 2015; Mirzaei et al., 2017; Mseddi et al., 2021; Sadia et al., 2017; Wangchuk et al., 2014) performed a study in Kirthar National Park, Sindh, Pakistan to determine the species richness and diversity distribution pattern in term of impact of environmental factors. (Hamid & Raina, 2019) studied the Phytodiversity and growth along elevation gradient in Central Himalaya, India. (Devlal & Sharma, 2008) determined variations in diversity of tree species dominating in Garhwal forest of Himalaya, India. (Arshad et al., 2008) studied Phytodiversity of Cholistan desert in Pakistan to delimit the effect of climatic and environmental factors on vegetation distribution patterns. They determined the relationship of soil characteristics with vegetation distribution pattern. (Gairola et al., 2009) studied species diversity and richness in Garhwal forest of Himalaya in India. (Bhattarai et al., 2014) explored species diversity in Karnali river valley of Himalaya in Nepal. (Wangchuk et al., 2014) studied species richness, diversity and density of Understory Vegetation in Himalaya forests situated in Bhutan. (Zhang et al., 2016) explored the phylogenetic diversity and altitudinal patterns of species diversity and across temperate mountain forests located in China. (Mseddi et al., 2021) examined the phyto-diversity distribution in terms of elevation gradient in Saudi Arabia. (Ahmad et al., 2021) conducted a study on prediction of soil seed bank of two different geographic arid zones (piedmont and alluvia plains) in Dera Ghazi Khan, Pakistan.

However, in Pakistan, for systematic research work on phyto-diversity and their correlations with the abiotic conditions for the improvement of general vegetation potentials of an area, no quantitative studies have been previously done in vast dry mountains. Thus, the detailed species composition in response to elevation gradients and edaphic variation of the study area is poorly understood and studies related to species phyto-diversity and richness using multivariate analysis from the studied area are lacking due to its remote location and inaccessibility. The current study was conducted to determine the impacts of geo-climatic factors on the distribution and diversity patterns of plant species from Dera Ghazi Khan and Kohe-Suleman regions of Pakistan. The study will provide ecological guidelines and base line information about the impact of geo-climatic factors on phyto-diversity for future studies.

II. MATERIALS AND METHODS

Study Area

The study area encompasses three geographical regions, like the riparian, piedmont zone and upper rocky slopes of Kohe Suleiman range mountain zones of Dera Ghazi Khan, Pakistan (Fig. 1). The riparian zone with Latitude 30°03′22″ N and Longitude 70°64′44″ E (Table 1) anticipated the bank of river Indus where the climate is climax type though humidity may somewhat higher. The river normally instigates to rise at the appearing of May and the rise continues with some interludes till the end of the July. It progressively subsidises reaching the winter level about the end of October. Windblown sand dunes are also met with in the inundation belt of the river and the determining factors are low rain fall. The second zone is piedmont area which is arid zone (29°59′5″ N Latitude and 70°18′15″ E Longitude (Table 1) which received water in the form precipitation and distributed among the lower slopes of

Suleiman ranges, at suitable elevations merging downwards with the sand dunes and upward with rocky slopes. The key factor is long dry season tempered with winter or spring precipitation with significantly low humidity. The temperature reaches to maximum in the June and July. Soils are universally dry and shallow and exhibited diverse geological formation from limestone, shales to crystalline rocks. The third zone is primarily upper rocky slopes of Suleiman Range Mountain (29°54′00″ N Latitude and 69°58′00″ E Longitude (Table 1). This area is composed of rugged, irregular and steep ridges and its adjacent alluvial plains. This is one of the bordering ranges between the Iranian plateau and the Indian subcontinent. Vegetation in this area showed great heterogeneity in terms of steep temperature and precipitation gradients.

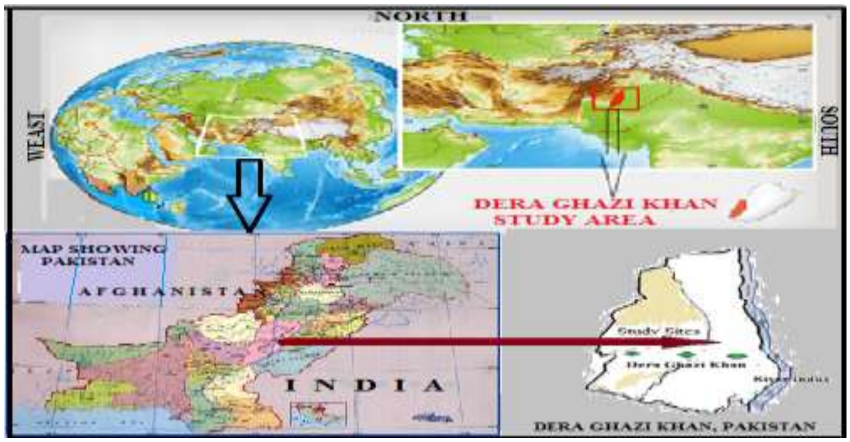

Fig. 1: Location map showing the three study sites (riparian zone, piedmont zone, and upper slopes rocky mountains) of Koh-Suleiman range mountain zones of Dera Ghazi Khan.

Table 1: Comparison of environmental factors among three study sites: riparian zone, piedmont zone, and upper rocky slopes mountains zones along elevation gradient.

Characteristics	Forest types		
	Riparian zone	Piedmont zone	Upper rocky slopes mountains zones
Locality/site	Indus river Ghazi Ghat	Sakhi Sarwar	Fort Manroo
Reserved area (km^2)	805	968	1188
Latitude	30°03′22″ N	29°59′5″ N	29° 54′ 0″ N
Longitude	70° 64′44″ E	70° 18′15" E	69° 58′00″ E
Site elevation (m a.s.l)	124	283	1970
Annual precipitation (mm)	104	215	203.92
Wind speed (ms^{-1})	6	9	14
% Relative humidity(summer)	18	22	78
% Rock cover stoniness	-	25 %	80%
Underlying lithology	Calcareous, sandy loam	Limestone	Granite
Dominant tree species	*Chloris barbata*	*Phragmites australis*	*Bothriosperum tenellum*
Common shrubs	*Acacia nilotica*	*Nerium oleander*	*Acacia jacquemontii*

Climate

The overall climate of the district Dera Ghazi Khan is dry with little rainfall and is classified as BWh (Tropical and subtropical desert climate). The winter is comparatively cold, and the climate is warm during the year, but it is very hot in summer (Fig. 2). The temperature during summer is usually about 115 °F (46 °C), while during winter season the temperature is as low as 40 °F (4 °C). The prevailing wind direction is north-south, however, because of the barren mountains of Kohe Suleman and the sandy soil of the area, windstorms are very common, and the temperatures are generally amongst the highest in Pakistan during summer. Fort Munro, located on the edge of Punjab province, has relatively cooler weather. In winter, scattered snowfall is also reported in this area. The average amount of precipitation for the year in district Dera Ghazi Khan is very low (Fig. 3) and area may receive light shower in May and September and the winter rain is scanty. The average annual rainfall seems to exhibit cyclic fluctuations with 2-3 years of much reduced precipitation followed by several years of more generous rainfall (Fig. 3).

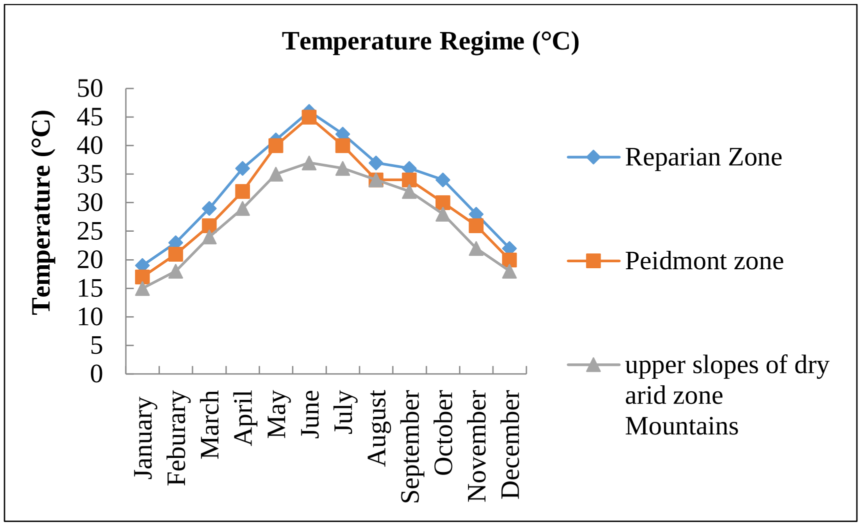

Fig. 2: Details of monthly temperature of the three study sites of Koh-Suleiman range mountain zones of Dera Ghazi Khan (Data obtained from Pakistan Metrological Department, Lahore, Punjab, Pakistan).

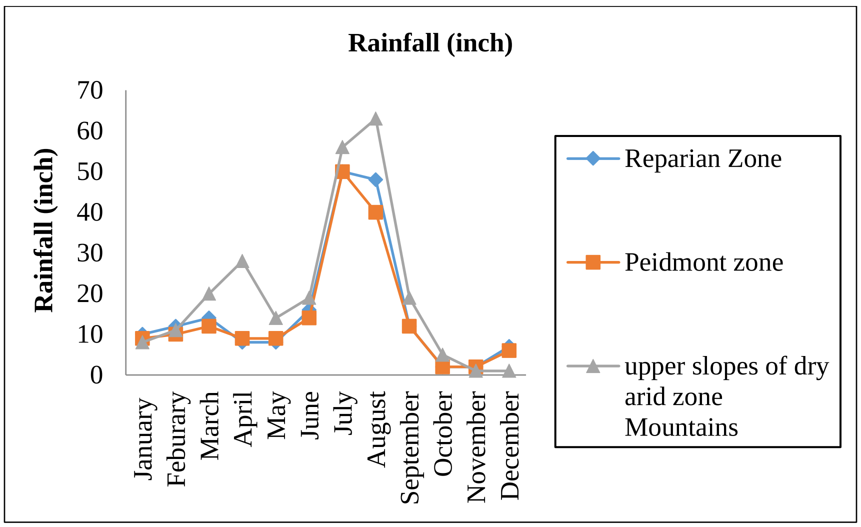

Fig. 3: Details of monthly rainfall (inch) in the three study sites Koh-Suleiman range mountain zones of Dera Ghazi Khan (Data obtained from Pakistan Metrological Department, Lahore).

Data collection

Broad field surveys were conducted throughout the three sites to determine major habitat types and then representative uniform areas were selected. Field sampling were done during spring and late monsoon seasons, which is thought to be the most appropriate time for sampling when most plant species were in their flowering stage and easily identifiable through their reproductive organs. All the vascular plants samples collected were identified and present in stands and identification was also done by comparing with herbarium specimen of the plants (Bibi et al., 2020). A 100 km long transect was laid down along the altitudinal gradient from 124 m (a.s.l) to 1970 m (a.s.l) comprising the entire vegetation variations expected along with the altitudinal gradient. After 100-meter distance, the main transect was marked systematically. At each point, five 1 m^2 quadrats (plots) were used for assessing the presence or absence of ground vegetation strata (annual, biennial, and perennial herbs). Quadrats of 4 × 4 m^2 were used to enlist shrubs and trees and a large size of quadrate of 10 x 10 m^2 was used for recording the tree species distribution. All the data recorded from replicated quadrats were pooled to a sampling stand and a total of 40 stands were examined and used for the vegetation analysis.

The direction of transect was from the south to the north and all the quadrats were marked within an estimated 2.0 m to the left side of the line transect (Fig. 4).

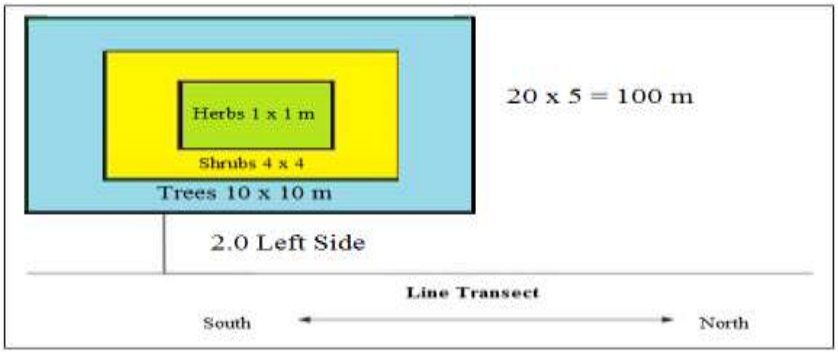

Fig. 4: Sampling scheme to study vegetation in the field (riparian zone, piedmont zone and upper slopes rocky mountains of Koh-Suleiman range mountain.

Soil sampling and chemical analysis

In each stand, a soil sample was taken from three different points and mixed to form a composite sample. Gravels present in soil samples were separated by sieving through 2 mm mash. Three sub-samples were drawn from this composite sample. To determine the edaphic heterogeneity, the sieved soil samples were subjected to chemical analysis. Soil chemical reaction (pH), Electrical conductivity, and available concentration of cations and anions were determined by using standard methods (Bibi et al., 2020; Qasba et al., 2017; Saima et al., 2018). Soil electrical conductivity was measured by using a digital conductivity meter at room temperature 25 ºC expressed in μScm^{-1}(CM- 30 ET digital EC meter). The amount of available phosphorus was estimated Spectrophotomatrically (Doğan & Gülser, 2019; Saima et al., 2018), available chloride was determined using a chloride analyzer (Sherwood, Model 926). Bivalent cations, magnesium and calcium contents were determined by titration method following Richard (1954) and Hussain (1989). Concentrations of monovalent cations (potassium, sodium) were determined by Flame photometer (PFP-7, Jenway) (Bibi et al., 2020; Qasba et al., 2017). Organic matter was resoluted from fresh soil by following the Walkley- Black wet digestion method (Bibi et al., 2020; Cramer, 2012). Total nitrogen content was determined calorimetrically with the micro Kjeldahl procedure with concentrated sulphuric acid. Soil pH of all samples was measured with digital pH meter (Bibi et al., 2020; Urooj et al., 2015).

Vegetation analysis

Cluster analysis was performed for classification of the vegetation data by using default option untransformed plant species presence absence data. Data were clustered based on agglomerative clustering method given by (Dasti et al., 2010; El-Sheikh et al., 2021; Urooj et al., 2015) and (Saima et al., 2018) integrating Farthest neighbouring as coefficient of distance similarity default option. Sites (stands) which were exhibiting more similar in their vegetation assemblage were depicted as being closer together in the hierarchical diagrammatic illustration. Sites that are to be different in score can be expected to have no species in common (Rahman et al., 2017). However, to delimit the possible intrinsic pattern in presence/ absence data of these species, site ordination analysis was applied by Detrended Correspondence Analysis (DCA). To determine the magnitude of variation in species composition along the ordination axes, the default option (down weighted rare species) of the program DECORANA was used and Rare species (having relative frequency <1) were excluded from the analysis. The Eigen values obtained for DCA axis 1 and 2 was relatively greater than the subsequent axes. As DCA axis I and II described most of the variations in the data set, only these axes were considered for further analysis. Scatter of classification groups from both procedures were plotted on overlays of ordination axes to evaluate the compatibility of the two methods of data simplification (Bibi et al., 2020; Saima et al., 2018; Urooj et al., 2015). Species diversity was estimated from Shannon diversity index for all 40 sites by following (Pielou, 1975). Scores on DCA axes 1 and 2 were used to test the relationship between variation in soil characteristics and distribution of plant species using Pearson correlation. Multivariate Statistical Package (MVSP version 3.22) and MINITAB- 21.1.0 version software Package was used for these analyses. The differences in soil parameters between the plants communities were assessed by using the analyses of variance (ANOVA). The plant species present absent data were normalized by an arcsine transformation prior to analyses of variance. Spearman Rank correlation was used to determine the relationships between soil characters and DCA axes I and axes II (Dasti & Agnew, 1994).

III. RESULTS AND DISCUSSION

Floristic composition

A total of 76 species belonging to 62 genera and 28 families were identified through field surveys from the riparian, piedmont zone, and upper slopes of Kohe Suleiman Range Mountains of Dera Ghazi Khan. Among the identified plant families, Lamiaceae, Asteraceae, Caryophyllaceae, and Rosaceae contributes major share (Table 2) while Polygonaceae, Ranunculaceae and Poaceae contribute little share in the overall vegetation composition of the studied zones.

Table 2: Top six plant families with highest number of genera and species from the study area.

Family	No. of genera	Percentage (%)	No. of species	Percentage (%)
Lamiaceae	9	12.00	11	12.09
Asteraceae	8	10.67	9	9.89
Caryophyllaceae	5	6.67	6	6.59
Rosaceae	5	6.67	5	5.49
Polygonaceae	4	5.33	5	5.49
Ranunculaceae	4	5.33	4	4.40
Poaceae	4	5.33	4	4.40

Floristic richness and diversity of species

The observed values of Shannon diversity (H') in the study area ranged between 2.93 to 2.49, where higher values indicated higher diversity. The values estimated for species richness (SR) ranged from 19.70 to 9.30, with higher values representing higher richness per unit area (Table 3).

Table 3: Indices of species richness and diversity.

Associations	SR	H´	B´	D´
A	19.70±3.38	2.93±2.93	2.06±0.15	0.94± 0.01
B	14.30±1.97	2.65±2.65	1.81±0.13	0.928±0.011
C	9.30±1.316	2.4932±2.4932	1.6758±0.2206	0.799±0.0879
***F & P*–values**	54.92***	17.26***	17.63***	32.89***

*** $P < 0.05$, **$P < 0.01$, ***$P < 0.001$, H= Shannon Wiener Diversity index; D= Simpson Index; B'= Brillion Diversity index, obtained by Normal cluster analysis.**

Classification

Three plant associations were identified by using the normal cluster analysis as shown in Fig. 5. The associations with few stands were merged to the nearest associations delineated by the cluster analysis. These associations are basically related to type of soils, geographical strata and altitude of the area from which plant samples were collected. The number and composition of plant associations were delineated at three levels in each association and are given in Table 4. The clusters showed three types of vegetation along the elevation gradients. As a result, three hierarchical clusters were formed i.e., mesic zone (association A), sandy alluvial plains (association B) and piedmont zone (association C).

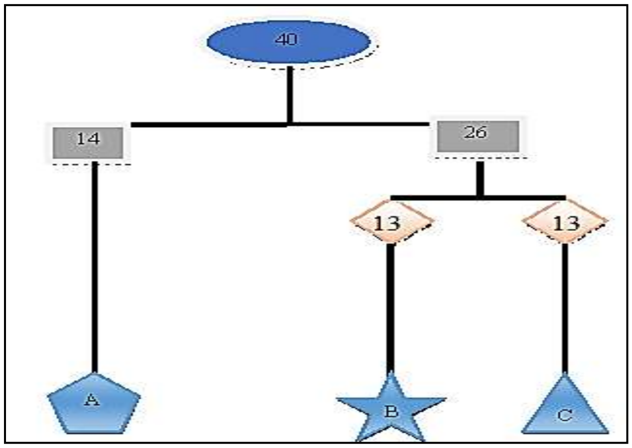

Fig. 5: Hierarchical diagram of 40 sampling stands segregated by normal cluster analysis.

i. Association A (*Chloris barbata-Eragrostis minor community*)

The association "A" delineated by normal cluster analysis was located on low elevation 114.3 m (a.s.l.) and is characterized by plant species like *Chloris barbata, Chenopodium album, Euphorbia prostrata, Eragrostis minor, Launaea procumbens, Nelumbo nucifera, Typha elephantine, Acacia nilotica, Enneapo gondesvauxii, Eragrostis barrelieri, Phalaris minor, Saccharum officinarum, Saccharum munja, Aerva persica, Pongamia pinnata* and *Capparis ducidua* (Fig. 6). These species were absent from other two associations recognized by normal cluster analysis. Most of the species included in this association are commonly found in and around the cultivated or abandoned crop fields. Among these species *Nelumbo nucifera, Chloris barbata, Chenopodium album, Euphorbia prostrata, Eragrostis minor, Launaea procumbens, Typha elephantine, Acacia nilotica* and *Enneapo gondesvauxii* were more frequent species while *Eragrostis barrelieri, Phalaris minor* and *Saccharum officinarum* were occasional species.

Fig. 6: Showing the *Chloris barbat-Eragrostis minor* community (association-A)

The component species of low land association (A) *Chloris barbata, Chenopodium album, Euphorbia prostrate, Eragrostis minor, Launaea procumbens, Nelumbo nucifera, Typha elephantina, Acacia nilotica, Enneapogon desvauxii, Eragrostis barrelieri, Phalaris minor, Saccharum officinarum, Saccharum munja, Aerua persica, Pongamia pinnata* and *Capparis ducidua* were confined to the riparian area, whereas *Demostachy abipinnata, Cymbopogon jawarancusa,Cyanodon dactylon, Calotropis procera, Alhagi aurorum, Ziziphus mauritiana, Rhayzia stricta, Pagnum harmala, Sueda fruticosa, Haloxylon salicornium, Calligonum polygonoides, Leptadenia pyrotechnica, Tamarix aphlla, Techomella undulate, Withiana coagulans* and *Cenchrus setigerus* were belonging to run on alluvial plains (Table 4).

Table 4: Observed relative frequency of species in each association type recognized by normal cluster analysis.

Species name	Associations	Species name	Associations

	A	B	C		A	B	C
Chloris barbata	3.75	-	-	*Calligonum polygonoides*	0.75	0.54	1.23
Chenopodium album	3.75	-	-	*Leptadenia pyrotechnica*	0.75	2.69	0.62
Euphorbia prostrate	3.75	-	-	*Tamarix aphylla*	0.75	1.08	1.23
Eragrostis minor	3.75	-	-	*Techomella undulate*	0.75	1.61	0.62
Launaea procumbens	3.75	-	-	*Withiana coagulans*	0.75	1.61	3.09
Nelumbo nucifera	3.75	-	-	*Cenchrus setigerus*	0.37	1.08	1.23
Typha elephantine	3	-	-	*Prosopis juliflora*	2.62	2.69	-
Acacia nilotica	3	-	-	*Sacchrum spontaneum*	1.87	0.54	-
Enneapogon desvauxii	3	-	-	*Salsola foetida*	1.5	1.08	-
Eragrostisbarrelieri	2.62	-	-	*Capparis cartilagnea*	1.5	3.23	-
Phalaris minor	2.62	-	-	*Daphne mucronata*	1.5	3.23	-
Saccharum officinarum	2.62	-	-	*Ebenus stellate*	1.5	2.69	
Saccharum munja	1.87	-	-	*Eclipta prostrate*	1.5	3.23	-
Aerva persica	1.87	-	-	*Euphorbia granulate*	1.5	2.69	-
Pongamia pinnata	1.87	-	-	*Fagonia bruguieri*	1.5	3.23	-
Capparis ducidua	1.12	-	-	*Farsetia hamiltonii*	1.5	3.23	-
Phragmites australis	-	2.69	-	*Cirsium arvense*	1.12	2.15	-
Nerium oleander	-	1.61	-	*Panicum hemitomon*	1.12	2.69	-
Bothriosperum tenellum	-	-	6.2	*Salvadoraoleoides*	1.12	0.54	-
Heliotropium eichwaldi	-	-	6.2	*Aristida depressa*	0.75	1.08	-
Scirpus maritimus	-	-	6.2	*Parthenium hysterophorus*	0.75	1.08	-
Dichanthium annulatum	-	-	6.2	*Solanum xanthocarpum*	0.75	1.61	-
Citrullus colocynthis	-	-	5.6	*Brachariareptans*	-	3.76	1.85
Gymnosporia royleana	-	-	5.6	*Hertia intermedia*	-	3.76	1.85
Acacia jacquemontii	-	-	4.9	*Panicum repens*	-	3.76	1.85
Acacia modesta	-	-	2.5	*Periplocaaphylla*	-	3.76	8.02
Piper longum	-	-	0.6	*Phyllanthus niruri*	-	3.76	1.85
Demostachya bipinnata	3.75	1.61	0.6	*Sophora mollis*	-	3.76	1.85
Cymbopogon jawarancusa	3.37	1.08	0.6	*Trianthema portulacastrum*	-	3.76	1.85
Cyanodon dactylon	3	2.69	0.6	*Datura stramonium*	-	2.15	1.23
Calotropis procera	3	2.69	1.9	*Olea cuspidate*	-	1.61	4.32
Alhagi maurorum	2.25	1.08	0.6	*Cenchrus ciliaris*	-	1.08	1.85
Ziziphus mauritiana	2.62	1.08	1.2	*Tribulus terristris*	-	1.08	1.23
Cynodon glabratus	1.5	1.08	0.6	*Depterygium glaucum*	1.12	-	0.62
Rhayzia stricta	1.12	2.69	1.2	*Haloxylon recurvum*	0.75	-	1.23
Peganum harmala	1.12	2.15	6.2	*Prosopis specigera*	0.75	-	1.23
Sueda fruticosa	1.12	1.61	1.2	*Ziziphus budhensis*	0.75	-	0.62

Haloxylon salicornium	1.12	2.15	1.2	*Ziziphus nummuclaria*	0.37	-	0.62

ii. Association B (*Nerium oleander-Leptadenia pyrotechnica* community)

This association is characterized by *Phragmites australis* and *Nerium oleander,* which were absent from all other associations identified by the normal cluster analysis (Table 4) and are designated as indicator species of this community. While species like *Demostachya bipinnata, Cymbopogon jawarncusa, Cyanodon dactylon, Calotropis procera, Alhagi maurorum, Ziziphus mauritiana, Rhayzia stricta, Pagnum harmala, Sueda fruticosa, Haloxylon salicornium, Calligonum polygonoides, Leptadenia pyrotechnica, Tamarixa phylla, Techomella undulate, Withiana coagulans* and *Cenchrus setigerus* were present in all three associations (Fig. 7). Similarly, *Prosopis juliflora, Sacchrum spontaneum, Salsola foetida, Capparis cartilagnea, Daphne mucronata, Ebenus stellata, Eclipta prostrate, Euphorbia granulate, Fagonia bruguieri, Farsetia hamiltonii, Cirsium arvense, Panicum hemitomon, Salvadora oleoides, Aristida depressa, Parthenium hysterophorus* and *Solanum xanthocarpum* were present in both associations A and B (Table 4).

Fig. 7: Showing *Nerium oleander -Leptadenia pyrotechnica* community (Association B).

iii. Association C (*Bothriosperum tenellum-Acacia jacquemontii* community)

This association is characterized by having *Bothrio sperumtenellum, Heliotropium eichwaldi, Scirpus maritimus, Dichanthium annulatum, Citrulus colocynthis, Gymnosporia royleana, Acacia jacquemontii, Acacia modesta* and *Piper longum* which were absent from all other associations identified by the normal cluster analysis. *Bothrio sperum, Heliotropium eichwaldi, Scirpus maritimus, Dichanthium annulatum, Citrulus colocynthis, Gymnosporia royleana* and *Acacia jacquemontii* (Fig. 8) were common species while *Acacia modesta* and *Piper longum* were occasional and the rare species respectively.

Fig. 8: Showing *Bothriosperum tenellum-Acacia jacquemontii* community (Association C)

Similarly, species like *Bracharia reptans, Hertia intermedia, Panicum repens, Periplocaaphylla, Phyllanthus niruri, Sophora mollis, Trianthema portulacastrum, Datura stramonium, Olea cuspidate, Cenchrus ciliaris,* and *Tribulus terristris* were present in both associations B and C. This association is situated at high elevation 809.85 m (a.s.l), segregated by normal cluster analysis and showed a much a topographic heterogeneity. Soil exhibited less edaphic characteristics in structure and composition. Most of the sampling stands were from stony desert zone and support the vegetation type which showed the litho-spheric site specific preferences.

Ordination

In the present condition, we can find that the species present in sandy substrate with low scores on axis-1 are towards the left on ordination and the species present in rocky habitat with high scores are towards the right of ordination, while species present in alluvial plains are in the middle of the ordination (Fig. 9). The results suggested the relative dominance of the species like *Chloris barbata, Chenopodium album, Euphorbia prostrate, Eragrostis minor, Launaea procumbens, Nelumbo nucifera*, *Typha elephantina, Acacia nilotica, Enneapo gondesvauxii, Eragrostis barrelieri, Phalaris minor, Saccharum officinarum, Saccharum munja, Aerva persica*, *Pongamia pinnata* and *Capparis ducidua* increased with the decrease in soil cations and anions (Table 5).

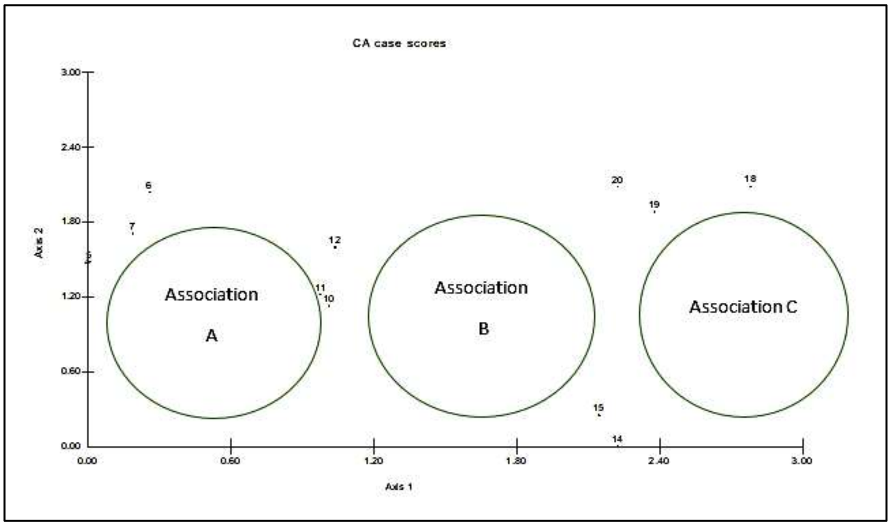

Fig. 9: Decorana (axes-I & axes-II) plot of the 40 stands showing three associations of plant species segregated by the normal cluster analysis.

The positive highly significant correlation between DCA axis-1 and elevation confirm that the elevation increased with the axis value score (*R* =0.655, Table 4.10, *F* = 14.88, *P*= 0.000, Table 5). The negative correlation between the scores on DCA axis-1 and soil EC (*R*= – 0.786 Table 7, *F* = 50.40, *P*= 0.000, Table 5) suggested that EC decreased with the increase in elevation. With the increase in score along DCA axis-1, EC of the substrate is decreased.

The lower end of transect exhibited maximum value (19.70), while minimum values were recorded in the topmost end of transect with species richness < 10 species per unit area. Similar distribution patterns of diversity indices were observed for H, B and D, which decreased with the increase in elevation. The correlation between altitude and diversity parameters was negatively significant (*r* = -0.712***, P < 0.05) as shown in Table 5.

Table 5: Spearman coefficients between (DCA) axis-I and axis II and soil parameters.

Geo-climatic factors	Axes-I	Axes–II
Elevation (m a.s.l)	0.655***	0.161^{NS}
Soil electrical conductivity EC(µS)	-0.786***	-0.287**
Soil reactions (pH)	-0.602***	-0.252^{NS}
Organic matter %	-0.719***	-0.483**
Available Bicarbonates (ppm)	-0.620***	-0.286^{NS}
Available Calcium (ppm)	-0.444***	-0.043^{NS}
Available Magnesium (ppm)	-0.263***	0.212^{NS}
Available Sodium (ppm)	-0.463**	0.110^{NS}
Available Potassium (ppm)	-0.727***	-0.135^{NS}
Available Phosphate (ppm)	-0.818***	0.068^{NS}
Available Chloride (ppm)	-0.368**	0.260^{NS}
No. of Species (SR)	-0.712***	-0.334^{NS}

Shannon Wiener Diversity (H´)	-0.698***	-0.283 ^{NS}
Simpson Diversity (D´)	-0.662***	-0.207n ^{NS}
Brillion Diversity (B´)	-0.698***	-0.283*

***P* < 0.05, ***P* < 0.01, ****P* < 0.001**

The soil of this association is rich with micro-nutrients and macro-nutrients as it receives the most drain water from hill torrents and rainwater as lying on run off. The soil of this association had high soil chemical reactions (pH = 7.91, F= 14.81, P <0.000) as given in Table 6. The soil contains mean values of EC (2.24 µS /cm) and organic matter (1.110 %) which are the maximum vales from the summit. The soil of this association showed maximum values of cationic and anionic values. The soil of this association had intermediate values of soil chemical reactions (pH = 7.27, F= 14.81, P<0.000). The soil possesses mean values of EC (1.94 µS/cm) and organic matter (0.712 %). The soil of this association showed intermediate values of cationic and anionic than Association A and C. The soil contained mean values of EC (1.39 µS/cm, F = 50.40, P < 0.000, Table 6, pH value (6.45, F = 14.75, P= 0.000) and organic matter (0.284 %, F = 50.83, P = 0.000, Table 6) which were minimum mean values of this association than rest of associations A and B. Soil showed minimum values of soil soluble cations and anions (Table 6). The species in this association preferred low pH values and less cations and anions.

Table 6: Mean values and standard deviation (SD) for soil variables and three types of associations identified by normal statistic divisive hierarchical process.

Variables		A	B	C	F-values
Elevation (m a.s.l)	Mean	375	483	2657	14.88***
	St Dev	33.99	86.50	2126	
Soil electrical conductivity EC (µS)	Mean	2.24	1.94	1.39	50.40***
	St Dev	0.11	0.19	0.31	
Soil reactions (pH)	Mean	7.91	7.27	6.45	14.75***
	St Dev	0.30	0.84	0.82	
Organic matter %	Mean	1.910	0.712	0.284	50.83***
	St Dev	0.29	0.69	0.11	
Available Bicarbonates (ppm)	Mean	113.2	99.45	86.23	26.99***
	St Dev	0.409	0.299	0.0951	
Available Calcium (ppm)	Mean	56.617	46.259	39.270	4.99*
	St Dev	2.172	0.0761	0.1379	
Available Magnesium (ppm)	Mean	0.232	0.21	0.156	1.70^{NS}
	St Dev	0.153	0.061	0.099	
Available Sodium (ppm)	Mean	13.833	11.666	9.631	1.32^{NS}
	St Dev	0.392	0.262	0.367	
Available Potassium (ppm)	Mean	372.14	316.46	276.08	30.98***
	St Dev	18.54	11.69	17.94	
Available Phosphate (ppm)	Mean	5.271	3.338	1.996	15.79***
	St Dev	1.222	1.028	0.870	
Available Chloride (ppm)	Mean	0.657	0.516	0.465	1.39^{NS}
	St Dev	0.505	0.198	0.339	
No. of Species	Mean	19.07	14.30	9.30	54.92***
	St Dev	3.385	1.974	1.316	

The spatial distribution of species along the DCA-axis I is also affected by soil chemistry. With the increase in score along ordination axis-I, the concentration of bivalent cations such as Ca2+ and Mg2+ is decreased. The stands located in the rocky zone of transect have less cations and anions than those of stony and partial sandy alluvial plains. The difference is probably a geological distribution which is sufficient to control the distribution of the species. Species such as *Bothriosperum tenellum, Heliotropium eichwaldi, Scirpusm aritimus, Dichanthium annulatum, Citrulus colocynthis, Gymnosporia royleana, Acacia jacquemontii, Acacia modesta* and *Piper longum* were the species in rocky area but not indicated in the alluvial plains. The association "C" favored the species which are site specific and survive at high elevation in limited source pattern of nutrients and these species were absent altogether in the alluvial plains. Hence water course had the least value of pH due to dilution as well as minimum vales at high elevation.

DISCUSSION

In the present study, a total of 76 species were predicted during summer season. The maximum number of species belong to the Poaceae family including *Aristida adscensionis, Brachiari areptans, Cenchrus ciliaris, Cenchchrus setiger, Chloris barbata, Cymbopogon jawarancusa, Cynodon dactylon, Cynodon glabratus, Demostachya bipinnata, Dichanthium annulatum, Enneapogon persicus, Eragrostis minor, Eragrostis barrelieri, Panicum hemitomon , Panicum repens, Phalaris minor, Phragmites australis, Saccharum munja, Saccharum officinarum* and *Saccharum spontaneum,* and these are followed by Fabaceae and Amaranthaceae families (Table 2). Among the plant families, Fabaceae, Amaranthaceae, Apocynaceae, Asteraceae and Poaceae were the most dominant contributing to the native flora, while Polygonaceae, Boraginaceae, Cucurbitaceae, and Chenopodiaceae were negligible with lesser number of species, with the exception of specific areas where the soil composition was predominantly sandy and deep. The pattern of distribution of these plant families recorded is in accordance with the findings of other studies conducted at the piedmont and alluvial plains of Pakistan (Arshad et al., 2008).

Variation in vegetation in relation to climatic dynamics and relationships with biotic component resulted in the distribution patterns of variety of plant species and individual species in similar habitat and community (A. Dasti & Agnew, 1994; Wazir et al., 2008). In the present study, a clear relationship between the three zones with elevation were recognized by the normal cluster analysis (Table 4) which shows these grouping of plant species are not randomly assembled. It was also observed that a little change in environmental factors and altitude have significant roles in the establishment of boundaries of community composition which are also determined by the soil cations and anions exchange capacity, altitude, chemical properties of soil and chemical reactions (Table 6).
The results obtained by DCA exhibited that altitude, soil chemical reactions (pH), electrical conductivity and bicarbonates show significant effect on distribution of species and composition of communities with R-value, P-value 0.002, and F-value 7.58 (Table 5). Similar pattern of vegetation zones encountered by edaphic factors were previously reported and indicated the comparison within the nearby areas (Khan et al., 2011; Khan et al., 2013).

It is understandable that the ordination along with the altitudinal gradient from the bottom to the top of transect is crucial in determining the composition of the community. There is a strongest positive correlation with elevation ($r = 0.655, P < 0.001$, Table 5) and is therefore associated with the three vegetation zones (Fig. 8). It is worth noticing that the high altitudes have low concentration of nutrients but associated with downward leaching of nutrients along with hill torrents. The negative correlation of pH, EC, N, Ca, Na, and Mg, provides a strong support in the favour of this interpretation and also supports the fact that there is diversity in the species distribution due to edaphic factors.

It was further noticed that human activities in terms of ecosystem degradation as well as complex habitats would give rise to higher turnover of species composition along an altitudinal gradient. However, the study was unable to trace out the impact of both spatial heterogeneity and human activities on phyto-diversity distribution and richness pattern with the help of the present or absence (frequency) of data. In fact, few species have ability to tolerate the entire spectrum of environments and can dominate throughout the gradient (Dasti et al., 2010; Wazir et al., 2008). The species with limited altitude always replace each other with some overlaps along mountainside (Dasti et al., 2010; Khan et al., 2013). The variation of species structure and community compositions among different sites (associations/community type) may reflect the profound differences in ecological traits among different plant functional types. The floristic composition of all the three sites was due to the influence of environmental factors on the plants and the reactions of plants according to their ecological adaptation in the area with striking climatic fluctuations. Special combination of ecological conditions may be significant factor in terms of shaping this observed distribution pattern of species (Gulshan et al., 2014).

At lower altitudes, the temperature and length of growing-seasons are adequate in the studied sites but soil moisture is not readily available which could be the reason for well-developed annual species. Despite the adequate precipitation at high altitudes, the low temperature would affect water availability, along with limited growing period and occurrence of early frosts giving rise to well-developed perennial herbs. The response of different plant species in relation to the adaptive strategies of plants to this soil moisture gradient is expected, i.e., plants may prolong life history cycle under those environments where water is sufficient but temperature is insufficient; however, under the opposed environments, an alternative response may take place, i.e. plants may shorten life history cycle. Previously in the studied regions, studies have focused on the conservation biodiversity however, research on the factors affecting the natural ecosystems is still undergoing. Current regulations and the enforcement of the law may be far from reaching the requirements of sustainable ecosystem management in the studied region (Ahmad et al., 2021; Dasti et al., 2010). Over the last decades, scientific research or conservational efforts focused mainly on the Himalayan moist temperate forests, located in northern areas of Pakistan due to their prominent implications both economically and ecologically as timber reasons (Mumshad et al., 2021;

Raja et al., 2020) while conservation of phyto-diversity in the Koh-Suleman range mountains has been neglected, especially at lower elevations piedmont zone (Sakhi Sarwar, lower foot hill arid zone) and upper rocky slopes located at high elevation (Fort Manru). There is need to develop biodiversity conservation strategies for all plant communities and their habitats with the establishment of topographic preferences of these species especially from the Koh-Suleman range mountains of Gera Ghazi Khan Pakistan.

CONCLUSION

The vegetation patterns and community composition of the studied three vegetation zones of Koh-Suleman Mountain range Dera Ghazi Khan, Pakistan with altitudinal gradient showed that the vegetation types significantly differ due to the diverse ecological conditions. The variation in altitude and topography of the environment are major indicators to determine the prominent vegetation zones in the Koh-Suleman Mountain range. Moreover the, physical and chemical properties of soil are crucial factors to delineate the distribution and diversity patterns of species. The distribution of community types, species composition and diversity could be better understood by assessing the geo-climatic factors with respect to elevational gradient of the mountain landscape.

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