Pak. J. Bot., 50(1): 41-49, 2018.

ECOLOGY AND SPECIES ASSOCIATION OF GRASS SPECIES IN RESPONSE TO ALTITUDINAL GRADIENT IN THE POTOHAR REGION

SANA FATIMA[1], FAROOQ AHMAD[1], MANSOOR HAMEED[1*] AND RASHID AHMAD[2]

[1]*Department of Botany, University of Agriculture, Faisalabad, Pakistan*
[2]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[*]*Corresponding author's e-mail: hameedmansoor@hotmail.com*

Abstract

An investigation was carried out to evaluate impact of altitudinal gradient on species composition and distributional pattern of individual grass species in the Potohar region. Vegetation was sampled by quadrat method, which were laid along a transect line at different selected sites. All ecological parameters like species composition, pair-wise association and distributional pattern, and community structure significantly changed with altitudinal gradient. Species with broad distributional range can be related to high degree of tolerance to a variety of environmental stresses. Species growing at low altitudes were different in their structure and contribution towards community structure. High altitude species are generally with restricted distributional range. Species richness was the maximum at moderate elevation because of better growth conditions. *Chrysopogon serrulatus* Trin., *Cymbopogon jwarancusa* (Jones) Schult. and *Cynodon dactylon* (L.) Pers. dominated the Potohar region, all showed significant association among themselves. Association usually existed between dominant species that shared similar resources. Species colonizing moister habitats, saline patches, drier hills. mountain slopes, low temperature ranges and sandy clayey soils, all have strong associations. Domination of species was similar up to 1200 m a.s.l., but species composition changed significantly along increasing elevation.

Key words: Species association; Distributional pattern; Richness; Altitude gradient; Community structure.

Introduction

The Potohar Plateau is located in extreme north of the Punjab province. Climatic conditions are warm and arid, with relatively low precipitation. It consists of 6 districts, northern and eastern districts (Jhelum, Rawalpindi and Attock) fall in high precipitation areas. Central and western districts (Mianwali, Khushab and Chakwal) receive with very low annual rainfall (Rashid & Rasul, 2011). The areas come into sub-Himalayan foothills, comprising of open scrub evergreen vegetation zone. Climate of mountain peaks like Sakesar, Diljabba, Tret and Kathar are much cooler that receive occasional snowfall during winters (Hameed *et al.,* 2008).

The Potohar region is quite rich in Poaceous flora that is economically very important for providing food for domestic animals and wildlife species, shelter for many birds and mammals, construction work, hay production and folk medicinal uses (Ahmad *et al*., 2010). Chaudhry *et al*. (2001) reported 41 species from Chumbi-Surla Wildlife Sanctuary, Ahmad *et al*. (2010) 60 grasses from Soone Valley, and Nawaz *et al*. (2012) 33 species from the Salt Range. Dominated grasses are *Heteropogon contortus* and *Cynodon dactylon* along foothills, while salt patches are dominated by *Ochthochloa compressa* and *Aeluropus lagopoides*. *Chrysopogon serrulates, Cymbopogon jwarancusa* and *Pennisetum orientalis* dominate moderate elevations, and higher altitudes have domination of *Aristida adscensionis*, *Bromus* spp. and *Lollium* spp. (Nawaz *et al*., 2012; Hameed *et al*., 2012). Other dicots that dominate the area are phulai (*Acacia modesta*), kao (*Olea ferruginea*) and baikhar (*Justicia adhatoda*). Lower hills are invaded by a number of alien invasive species like gajarbooti (*Parthenium hysterophorus*), sanatha (*Dodonaea viscosa*), panchphulli (*Lantana camara*) and masquat (*Prosopis glandulosa*) (Hameed *et al.,* 2012).

Studies on vegetation response on climatic change are focused in mountainous regions in recent eras. A small increase in altitude can change the complete vegetation structure, species distributional pattern and species composition (Parmesan, 2006) along with physiographic factors and other climatic factors (Pauli *et al.,* 2007). Rise in elevation is directly related to decrease in atmospheric pressure and temperature, but other factors like soil nutrient and moisture availability, growth period, irradiance, wind velocity, etc. may also affect (Charrier *et al.*, 2015). Grasses generally have more potential to adapt environmental extremes, therefore species that are widespread in distribution are expected to have resistance to a variety of habitat types (Vitasse *et al.,* 2009).

Ecological factors like density, frequency and percent cover are among the most influential parameters that significantly alter along altitudinal gradient (Lenoir *et al.,* 2008). This can change entire structure and composition of vegetation community, dominance of individual species and structural and functional attributes of inhabitant species (Bogenrieder & Klein, 1982; Kofidis *et al.,* 2003). The present investigation was conducted to evaluate changes in species richness, association among different species and their dominance along altitudinal gradient. It was hypothesized that altitudinal gradient may have a significant impact on distribution pattern of individual species in the Potohar region.

Material and Methods

Vegetation was studied at 7 different altitudinal ranges in the Potohar region, i.e., from 200 m to 1400 m a.s.l. The other sides were selected, each with a difference of 200 m elevation. Vegetation sampling was done at three distinct regions at each altitudinal range in the Potohar region, each site was separated by at least 50 km. Each region was subdivided on the basis of percent slope, i.e., c. 20, 30 and 45%. Three transect line (100 m long) were selected at each study site and 5 quadrats (1 x 1) were laid along each transect line (Fig. 1). High-pixel photographs of all grasses and their habitats were taken, and plant samples were placed in the Herbarium, Department of Botany, University of Agriculture, Faisalabad. Data for density, frequency and cover were recorded according to Greig-Smith (1983), and then their relative values, importance value and species association were calculated as follows:

$$\text{Density of a species X} = \frac{\text{Total number of individuals of species X}}{\text{Total area of quadrats}}$$

$$\text{Relative density of species X} = \frac{\text{Density of species X}}{\text{Total plant density}} \times 100$$

$$\text{Frequency of a species X} = \frac{\text{Number of quadrats with species X}}{\text{Total number of quadrats sampled}}$$

$$\text{Relative frequency of species X} - \frac{\text{Frequency of species}}{\text{Total plant density}} \times 100$$

$$\text{Cover of a species X} = \text{Total \% cover of species X}$$

$$\text{Relative cover of species X} = \frac{\text{Cover of species X}}{\text{Total plant cover}} \times 100$$

$$\text{Importance value of species X} = \text{Relative density} + \text{Relative frequency} + \text{Relative cover}$$

Association between two species was calculated in accordance with Hubalek (1982) on the basis of presence and absence of both species together, and thereafter applied χ^2 test to evaluate significance level at p>0.001, 0.01 and 0.05 of pair wise associations (Ludwig & Reynolds, 1988).

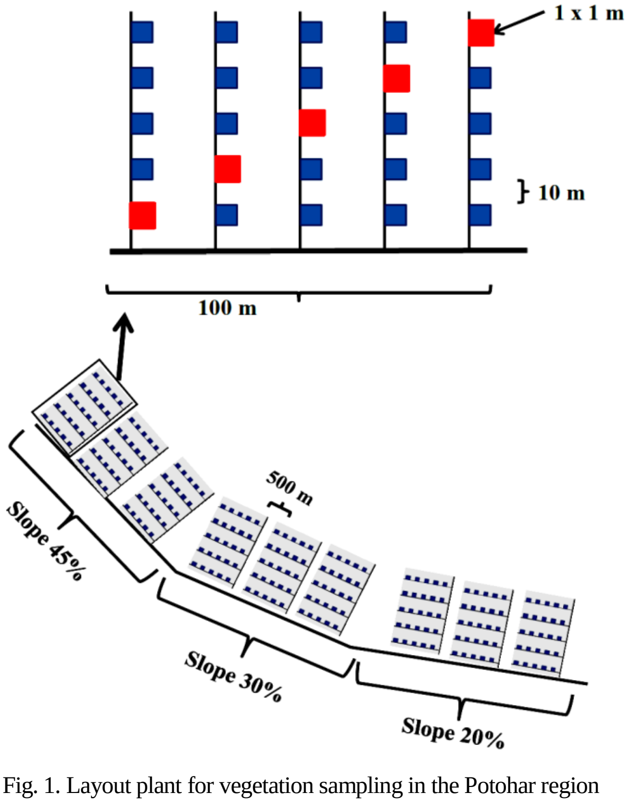

Fig. 1. Layout plant for vegetation sampling in the Potohar region (Red square from where soil samples were taken from each study site for physicochemical characteristics)

Results and Discussion

Six grasses were selected for detailed morpho-anatomical and physiological characteristics, all are widespread in distribution and recorded from all altitudinal ranges (Table 1). *Cynodon dactylon* is a stoloniferous species that dominated 600 to 1000 m elevations. *Aristida adscensionis* is a short-lived perennial that is widespread in distribution, little scattered in distribution but not a dominant component of vegetation at any altitudinal range. *Chrysopogon serrulatus* and *Cymbopogon jwarancusa* are tufted perennials, the former dominated 600-1200 m a.s.l., and the later lower elevations (200-400 m a.s.l.). *Dichanthium annulatum*is a geneculately ascending perennial and *Pennisetum orientalis* a tussock-forming grass, both with patchy distribution found all over the Potohar region (Table 1).

Lower altitudes (200-400 m a.s.l.) had the dominance of *Ochthochloa compressa* among other grasses, which is a spreading species. Quite a few grasses dominated higher elevations. *Imperata cylindrica*, *Dactyloctenium scindicum* and *Heteropogon contortus* dominated 600 m elevation, while *Aristida mutabilis*, *Dichanthium foveolatum*, *Digitaria adscendens* and *Sporobolus coromandelianus* 800 m elevation. *Desmiostachya bipinnata* was the most dominant vegetation component at 1000 m a.s.l., however *Dactyloctenium scindicum* was the other species that was recorded quite frequently (Table 1). *Heteropogon contortus* and *Dactyloctenium scindicum* were among the dominant species at 1200 m elevation. Vegetation structure altogether changed at the highest elevation (1400 m a.s.l.), where the most dominant species was *Koeleria cristata*. Other dominant species were *Arthraxon lancifolius*, *Koeleria macrantha* and *Lolium persicum*, all were not recorded from lower elevations. Species richness increased with increase in elevation up to 800 m a.s.l., but then decreased at 1000 m a.s.l. A little stability in species richness was recorded thereafter but species composition significantly altered (Table 1).

Relative values for density, frequency and percent cover at various altitudinal ranges are presented in Tables 2 and 3. Low altitude (200 m a.s.l.) was completely dominated by two grasses, *Cymbopogon jwarancusa* and *Chrysopogon serrulatus,* while other grasses showed patchy distribution. *Ochthochloa compressa* and *Cynodon dactylon* were relatively more frequent than the others. At 400 m elevation, the dominance was again shared by two grasses in a similar way, i.e., the most dominant *C. jwarancusa* and this was followed by *C. serrulatus. Ochthochloa compressa* also shared dominance at many places but its distribution was little scattered. Other important grasses were *Saccharum spontaneum* and *Aristida cyanantha*, both shared specific habitat within the study sites.

Table 1. Species richness (SR) and dominance of grass species in the Potohar region along altitude gradient.

Selected gasses						Other grasses							SR	Altitude
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Ala* *Lpe*	*Bca* *Lpm*	*Bja* *Pin*	*Bra* *Sco*	*Icy*	*Kcr*	*Kma*	17	1400 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Amu* *Hco*	*Cdo* *Sgr*	*Dsc* *Sar*	*Dbi*	*Dfo*	*Dsa*	*Epi*	16	1200 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Amu* *Epe* *Sio*	*Cpe* *Emi*	*Dsc* *Hco*	*Dbi* *Icy*	*Dfo* *Pmi*	*Dsa* *Pka*	*Dad* *Sba*	21	1000 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Ara* *Dbi* *Ete* *Sgr*	*Amu* *Dfo* *Fru* *Ssp*	*Bre* *Dad* *Hco* *Sar*	*Cpe* *Dlo* *Tvi* *Sco*	*Cst* *Dsa* *Oco*	*Dae* *Epe* *Pat*	*Dsc* *Emi* *Rcr*	31	800 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Ara* *Dci* *Icy* *Sio*	*Cpe* *Dsa* *Ppa*	*Cst* *Ecr* *Sbe*	*Dae* *Epi* *Ssp*	*Dsc* *Hcm* *Svi*	*Dbi* *Hco* *Sha*	*Dfo* *Tvi* *Sco*	28	600 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Ara* *Ssp*	*Acy* *Sar*	*Amu*	*Hco*	*Oco*	*Pan*	*Sgr*	15	400 m
Aad	*Cse*	*Cjw*	*Cda*	*Dan*	*Por*	*Dfo*	*Dad*	*Dsa*	*Oco*	*Sgr*	*Ssp*		12	200 m

The most dominant among selected grasses		The most dominant among other grasses	
Dominant among selected grasses		Dominant among other grasses	

Aad: Aristida adscensionis, Acy: Aristida cyanantha, Ala: Arthraxon lancifolius, Amu: Aristida mutabilis, Amc: Apluda mutica, Ara: Achrachne Racemosa, Bac: Bromus catharticus, japonicus, Bra: Bormus racemosa, Bre: Brachiaria reptans, Cda: Cynodon dactylan, Cdo: Chloris dolichistachya, Cwj: cymbopogon jwarancusa, Cpe: Cenchrus pennisetiformis, Cse: Chrysopogon serrulatus, Cst: Cenchrus setigerus, Dlo: Digitaria ciliaris, Dfo: Dichanthium feveolatum Dsa: Digitaria sanguinalis, Dsc: dactyloctenium scindicum Ecr: Echinochloa crus-galli, Emi: Eragrostis minor, Epe: Enneapogon persicus, Epi: Eragrostis Pilosa, Etn: Eragrostis tenella, Fru: Festuca rubra, Hcm: Hemarthria compressa, Hco: Heteropogon contortus, Icy: Imperata cylindrical, Kcr: Koeleria cristata, Kma: Koeleria macrantha, Lpe: Lolium peremne, Lpm: Lolium persicum, Oco: Ochthochloa compressa, Pan: Panicum antidotale, Pat: Panicum atrosanguineum, Pin: Poa infirma, pka: Phragmites karka, Pmi: Phalaris minor, Por: Pennistum orientale, Ppa: Paspalum paspaloides, Rcr: Rostraria cristata, Sar: Sporobolus arabicsu, Sco: Sporobolus coromandelianus, Sba: Saccharum bengalense, Sca: stipa capensis, Sgr: Saccharum griffithii, Sha: Sorghum halepense, Sio: Sporobolus ioclados, Ssp: Saccharum spontaneium, Svi: Setaria viridis, Tvi: Terapogon villusus

Chrysopogon serrulatus and *Cynodon dactylon* jointly dominated 600 m elevation. *Cymbopogon jwarancusa* and *Imperata cylindrica* were the other species recorded very frequently at 600 m a.s.l. Other important grasses at this altitudinal range were *Dactyloctenium scindicum*, *Desmostachya bipinnata*, *Hemarthria compressa* and *Heteropogon contortus*, all were recorded frequently in the region. Distributional pattern of grass species was more or less similar to that recorded for 600 m elevation, the most dominant species were *C. serrularus* and *C. dactylon*, which were followed by *C. jwarancusa*. Other important species were *Digitaria adscendens*, *Ochthochloa compressa* and *Saccharum spontaneum*, all dominated some specific microhabitats.

Three species collectively shared dominance at 1000 m a.s.l., *Chrysopogon serrulatus* and *Desmostachya bipinnata* were the most dominant species. Other important species was *C. dactylon*, which was recorded abundantly at this elevation. *Desmostachya bipinnata* was recorded frequently but little scattered in distribution. *Chrysopogon serrulatus* solitarily dominated altitudinal range of 1200 m a.s.l. Three species, *C. jwarancusa*, *D. scindicum* and *H. contortus* were the other dominant species that shared almost equally the vegetation composition at this altitudinal range. Other important grasses were *C. dactylon* and *A. mutabilis* with little sporadic in distribution. *Koeleria cristata* was the most dominant species along with *Lolium persicum* and *K. macrantha* that formed major composition of vegetation at 1400 m elevation. Other important species were *Arthraxon lancifolius* and *Lolium perenne,* but with scattered distributional pattern.

Paired association between grasses in the Potohar region varied significantly with increase in elevation. Quite a few associations were recorded at 200 m a.s.l. Paired association was significant ($p<0.001$) between *C. serrulatus* and *C. jwarancusa* at this altitudinal range (Fig. 2). The former showed significant ($p<0.01$) relationship with *C. dactylon.* Significant correlation was also recorded for *C. dactylon* with *C, jwarancusa* and *O. compressa*. The most dominant grasses, *C. serrulatus* and *C. jwarancusa*, showed significant ($p<0.001$) association at 400 m a.s.l. (Fig. 1), but both these species significantly associated with *O. compressa* ($p<0.01$) and *S. griffithii* ($p<0.05$). A significant association was also recorded between *A. cyanantha* and *S. griffithii.*

Table 2. Ecological parameter in the Potohar region up to 800 m a.s.l.

Grass species	RD	RF	RC	IV	Grass species	RD	RF	RC	IV
200 m a.s.l.									
Aristida adscensionis	1.12	1.12	0.96	3.20	*Digitariaadscendens*	1.09	0.67	0.48	4.24
Chrysopogon serrulatus	30.81	26.64	19.92	77.27	*Digitariasanguinalis*	0.95	1.24	1.00	8.20
Cymbopogonjwarancusa	47.07	28.97	36.78	112.06	*Ochthochloacompressa*	13.85	2.03	2.19	17.00
Cynodondactylon	1.22	1.18	0.16	15.56	*Panicum orientale*	3.25	1.32	2.85	9.28
Dichanthiumannulatum	1.22	0.67	0.40	5.29	*Saccharumgriffithii*	0.67	1.96	2.45	9.08
Dichanthiumfoveolatum	3.54	3.18	2.67	9.39	*Saccharumspontaneum*	0.38	1.05	1.13	4.66
400 m a.s.l.									
Acrachneracemose	0.11	1.23	0.08	1.42	*Heteropogoncontortus*	0.75	2.45	0.45	3.65
Aristidaadscensionis	1.21	2.01	1.01	4.23	*Ochthochloacompressa*	12.89	10.86	11.18	34.93
Aristidacyanantha	1.97	5.14	3.90	11.01	*Panicum antidotale*	1.13	1.23	1.34	3.70
Aristidamutabilis	1.80	3.17	1.20	6.18	*Pennisetumorientale*	0.33	1.45	0.29	2.07
Chrysopogonserrulatus	27.01	24.06	24.43	75.49	*Saccharumgriffithii*	0.56	2.76	1.84	5.16
Cymbopogonjwarancusa	41.30	28.78	41.90	111.98	*Saccharumspontaneum*	1.65	7.55	3.52	12.73
Cynodondactylon	1.56	2.25	1.39	5.20	*Sporobolusarabicus*	0.01	0.43	0.01	0.44
Dichanthiumannulatum	1.10	1.01	1.09	3.20					
600 m a.s.l.									
Acrachneracemose	0.04	0.54	0.03	0.61	*Echinochloa crus-galli*	0.03	0.57	0.03	0.62
Aristidaadscensionis	0.72	2.72	0.28	3.72	*Eragrostispilosa*	0.25	1.08	0.52	1.84
Cenchruspennisetiformis	0.80	2.28	0.51	3.59	*Hemarthriacompressa*	6.02	1.14	3.58	10.73
Cenchrussetigerus	0.03	0.57	0.03	0.62	*Heteropogoncontortus*	4.24	5.50	5.03	14.75
Chrysopogonserrulatus	15.11	9.35	21.64	46.10	*Tetrapogonvillosus*	0.21	1.08	0.11	1.39
Cymbopogonjwarancusa	7.70	5.47	8.97	22.14	*Imperatacylindrica*	9.17	1.14	8.68	18.98
Cynodondactylon	20.23	5.98	17.22	43.42	*Paspalumpaspaloides*	0.03	0.57	0.03	0.62
Dactylocteniumaegypticum	0.58	0.57	0.51	1.65	*Pennisetumorientale*	1.10	1.00	1.10	3.20
Dactylocteniumscindicum	7.19	3.83	3.94	14.96	*Saccharumbengalense*	0.17	1.71	0.87	2.75
Desmostachyabipinnata	3.52	3.41	3.83	10.76	*Saccharumspontanium*	1.52	2.28	1.89	5.68
Dichanthiumannulatum	1.48	2.25	1.33	5.06	*Setariaviridis*	0.03	0.57	0.03	0.62
Dichanthiumfoveolatum	2.98	2.78	1.64	7.40	*Sorghum halepense*	0.20	1.11	0.28	1.58
Digitariaciliaris	0.12	0.57	0.05	0.74	*Sporoboluscoromendelianus*	1.66	1.08	1.03	3.76
Digitariasanguinalis	2.28	2.72	2.11	7.10	*Sporobolusioclados*	2.16	4.40	0.87	7.42
800 m a.s.l.									
Achrachneracemose	0.26	0.44	0.08	0.78	*Digitariasanguinalis*	0.04	0.14	0.03	0.20
Aristidaadscensionis	0.51	0.79	0.29	1.59	*Enneapogonpersicus*	0.19	0.55	0.05	0.80
Aristidamutabilis	4.60	1.64	1.70	7.93	*Eragrostis minor*	0.99	0.89	0.34	2.19
Brachiariareptans	0.11	0.49	0.05	0.65	*Eragrostistenella*	0.58	1.03	0.33	1.93
Cenchruspennisetiformis	0.49	2.16	0.25	2.90	*Festuca rubra*	0.39	0.23	0.24	0.85
Cenchrussetigerus	0.18	0.63	0.08	0.86	*Heteropogoncontortus*	0.03	0.11	0.01	0.14
Chrysopogonserrulatus	15.61	3.76	16.16	25.55	*Tetrapogonvillosus*	0.64	0.15	0.86	1.65
Cymbopogonjwarancusa	13.04	3.48	13.55	18.06	*Ochthochloacompressa*	3.56	1.35	2.09	7.01
Cynodondactylon	17.06	2.38	13.35	22.78	*Panicum atrosanguinium*	0.06	0.63	0.06	0.74
Dactylocteniumaegyptium	0.30	1.05	0.11	1.46	*Pennisetumorientale*	0.30	0.40	0.50	1.20
Dactylocteniumscindicum	2.40	1.14	0.56	4.09	*Rostrariacristata*	0.20	0.40	0.50	0.11
Desmostachyabipinnata	0.60	0.74	0.40	1.73	*Saccharumgriffithii*	0.35	0.45	0.11	0.90
Dichanthiumannulatum	1.28	0.86	0.50	2.64	*Saccharumspontanium*	2.16	2.35	6.51	11.04
Dichanthiumfoveolatum	3.55	2.56	1.98	8.05	*Sporobolusarabicus*	0.24	0.15	0.29	0.68
Digitariaadscendens	4.59	3.40	4.01	11.98	*Sporoboluscoromandelianus*	3.15	2.06	1.40	6.61
Digitarialongifloea	0.09	0.35	0.11	0.54					

RD: Relative density, RF: Relative frequency, RC: Relative cover, IV: Importance value

The most dominant (*C. serrulatus*) significantly associated with *C. jwarancusa* and *C. dactylon* ($p<0.001$), and with *D. scindicum* and *Heteropogon contortus* ($p<0.01$) at 600 m a.s.l. (Fig. 3) *Cynodon dactylon* showed significant association with number of grasses at $p<0.05$, i.e., *D. scindicum, D. bipinnata, D. annulatum, D. foveolatum, D. sanguinalis, H. contortus* and *S. ioclados.* A significant relationship also recorded for *D. scindicum* with *D. bipinnata* ($p<0.01$), and with *D. foveolatum, H. compressa, H. contortus* and *S. ioclados* ($p<0.05$). *Sporobolus ioclados* also showed association with *D. bipinnata* and *H. contortus* ($p<0.05$), whereas *I. cylindrica* with *S. spontaneum.*

Quite a few associations were recorded at 800 m elevation (Fig. 4). The most dominant *C. serrulatus* showed association with *C. dactylon* and *D. adscendens* at $p<0.001$ and with *C. jwarancusa, D. foveolatum* and *S. coromandelianus* at $p<0.01$. *Cynodon dactylon* significantly associated with *D. foveolatum*, *D. adscendens* and *S. spontaneum* at $p<0.001$. *Chrysopogon serrulatus, C. jwarancusa* and *C. dactylon* comprised the significant proportion of vegetation at 800 m a.s.l., and all these showed association at $p<0.05$ with a number of grass species including *A. mutabilis, C. pennisetiformis, O. compressa* and *S. coromandelianus*.

Table 3. Ecological parameter in the Potohar region at 1000 m a.s.l. and above.

Grass species	RD	RF	RC	IV	Grass species	RD	RF	RC	IV
1000 m a.s.l.									
Aristidaadscensionis	0.28	0.01	0.01	0.31	*Digitariaadscendens*	0.48	0.14	0.07	0.70
Aristidamutabilis	1.80	0.77	0.43	3.00	*Enneapogonpersicus*	0.49	0.09	0.04	0.63
Cenchruspennisetiformis	1.77	1.47	1.33	4.57	*Eragrostis minor*	0.95	0.16	0.09	1.19
Chrysopogonserrulatus	6.55	14.67	11.54	32.77	*Heteropogoncontortus*	0.86	0.14	0.09	1.09
Cymbopogonjwarancusa	3.22	3.50	2.89	9.61	*Imperatacylindrica*	0.69	0.73	0.87	2.28
Cynodondactylon	3.02	14.58	6.92	24.52	*Pennisetumorientale*	1.41	0.44	0.46	2.31
Dactyloctenumscindicum	2.02	5.14	3.33	10.49	*Phalaris minor*	0.24	0.02	0.02	0.27
Desmostachyabipinnata	7.27	13.59	11.03	31.89	*Phragmites karka*	0.24	0.02	0.02	0.27
Dichanthiumannulatum	0.41	0.35	0.28	1.04	*Saccharumbangalense*	0.24	0.02	0.02	0.27
Dichanthiumfoveolatum	1.25	1.57	0.84	3.66	*Sporobolusioclados*	1.60	1.40	0.77	3.78
Digitariasanguinalis	2.04	0.94	0.67	3.65					
1200 m a.s.l.									
Aristidaadscensionis	0.29	0.31	0.16	0.76	*Dichanthiumannulatum*	0.13	0.21	0.26	0.60
Aristidamutabilis	4.18	1.81	1.99	7.98	*Dichanthiumfoveolatum*	0.38	1.34	0.15	1.87
Chloris incomplete	1.91	1.41	0.45	3.77	*Digitariasanguinalis*	1.87	2.42	1.16	5.45
Chrysopogonserrulatus	22.37	10.03	17.26	49.65	*Eragrostis minor*	0.70	1.19	0.36	2.25
Cymbopogonjwarancusa	14.01	4.51	8.17	26.69	*Heteropogoncontortus*	9.74	6.93	6.37	23.03
Cynodondactylon	4.85	2.46	2.34	9.65	*Pennisetumorientale*	0.13	0.12	0.25	0.50
Dactylocteniumscindicum	16.96	4.71	7.30	28.97	*Saccharumgriffithii*	0.25	0.96	0.45	1.66
Desmostachyabipinnata	2.11	1.19	1.77	5.07	*Sporobolusarabicus*	0.85	1.50	0.79	3.14
1400 m a.s.l.									
Aristidaadscensionis	3.42	2.24	1.39	0.60	*Ipmeratacylindrica*	18.55	4.59	10.63	3.37
Arthraxonlancifolius	0.11	0.45	0.06	7.06	*Koeleriacristata*	8.51	4.02	5.24	33.77
Bromuscatharticus	0.81	0.92	0.42	0.61	*Koeleriamacrantha*	2.90	2.75	1.96	17.77
Bromus japonicus	1.06	0.89	0.58	2.15	*Loliumperenne*	10.86	4.46	7.42	7.61
Bromusramosus	1.06	0.89	0.58	2.54	*Loliumpersicum*	0.85	0.89	0.44	22.74
Chrysopogonserrulatus	0.12	0.13	0.35	0.60	*Pennisetumorientale*	0.11	0.11	0.38	0.60
Cymbopogonjwarancusa	0.24	0.17	0.56	0.97	*Poainfirma*	0.05	0.46	0.02	2.18
Cynodondactylon	0.13	0.11	0.36	0.60	*Sporoboluscoromandelianus*	0.11	0.45	0.06	0.53
Dichanthiumannulatum	1.39	0.92	0.83	0.60					

RD: Relative density, RF: Relative frequency, RC: Relative cover, IV: Importance value

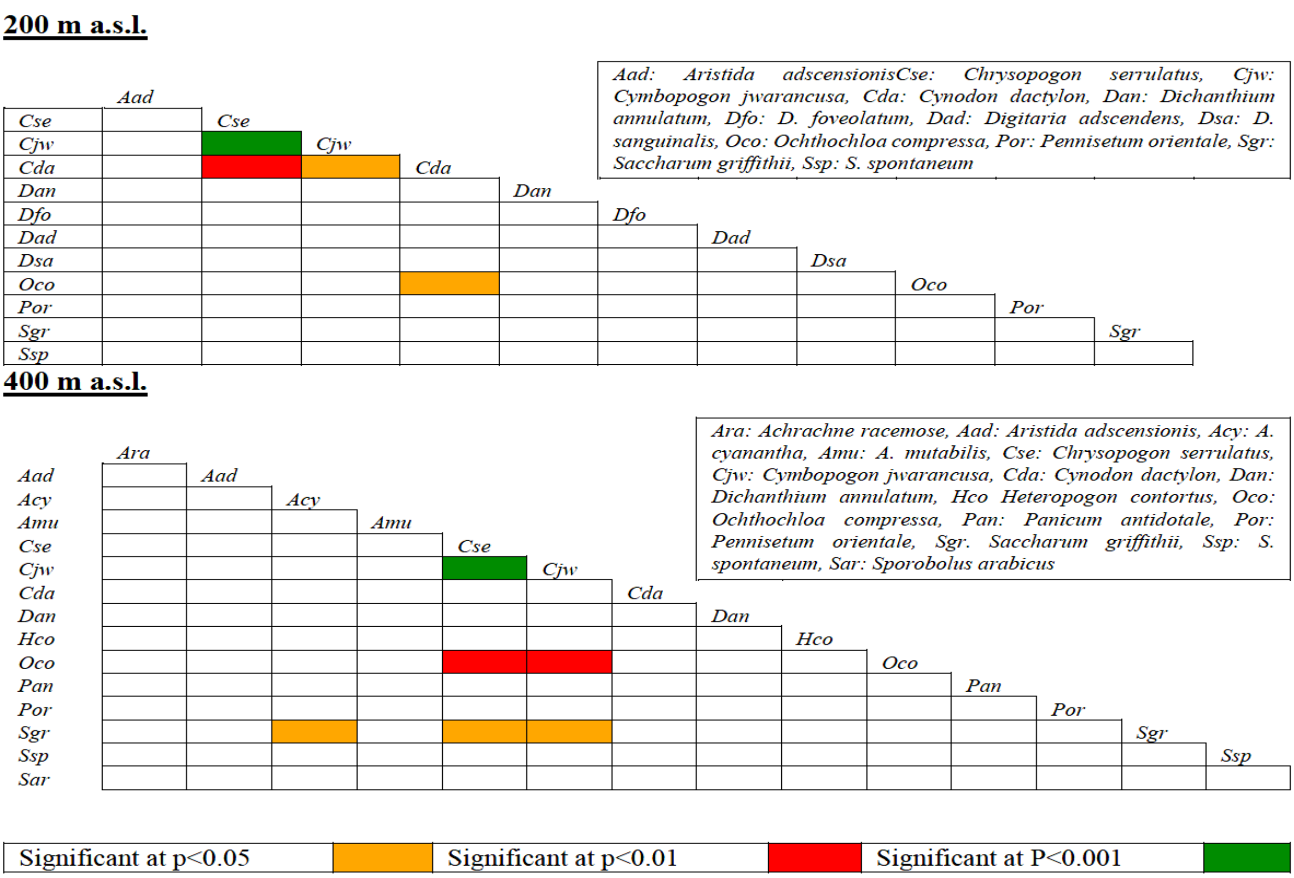

Fig. 2. Species association among grasses 200 and 400 m a.s.l. in the Potohar region.

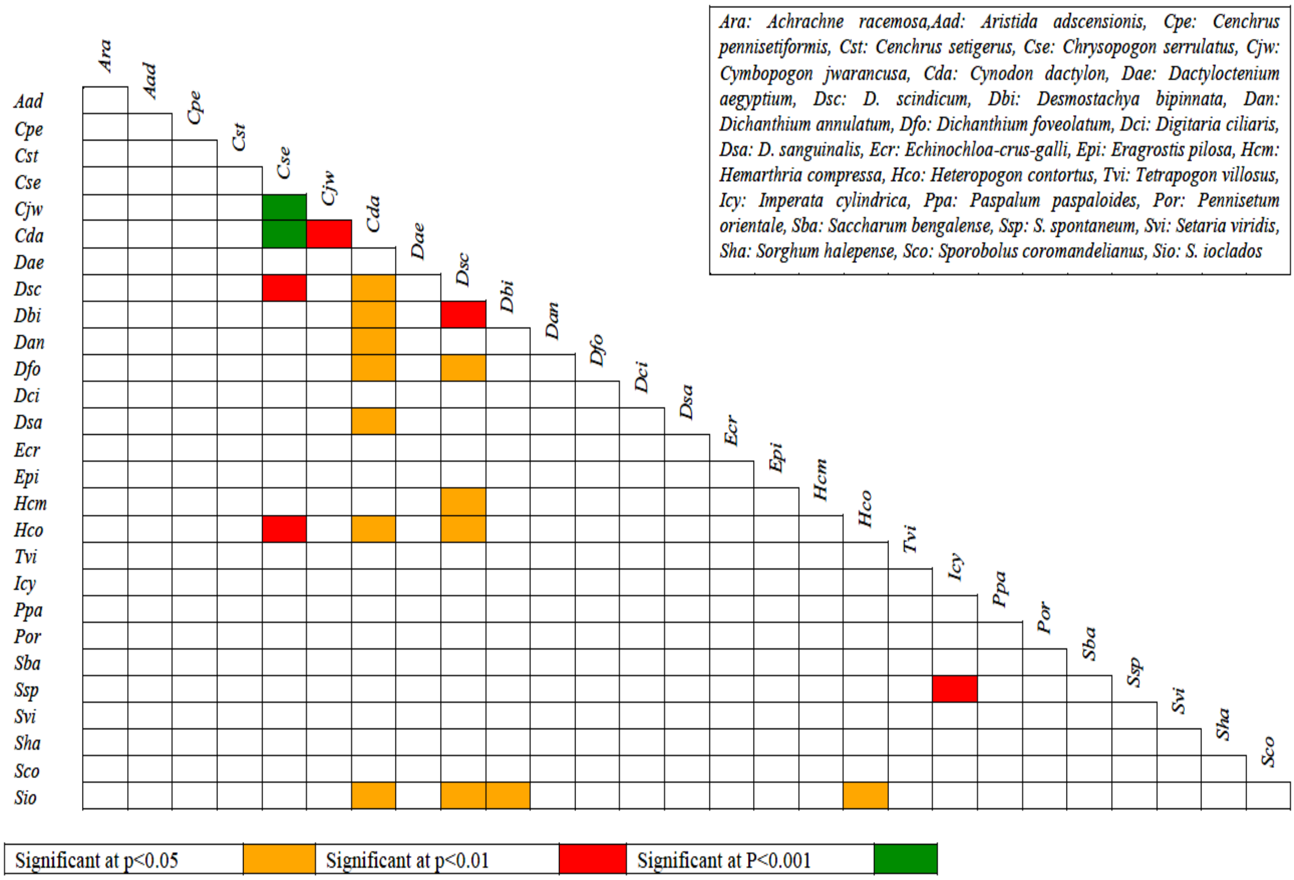

Fig. 3. Species association among grasses at 600 m a.s.l. in the Potohar region.

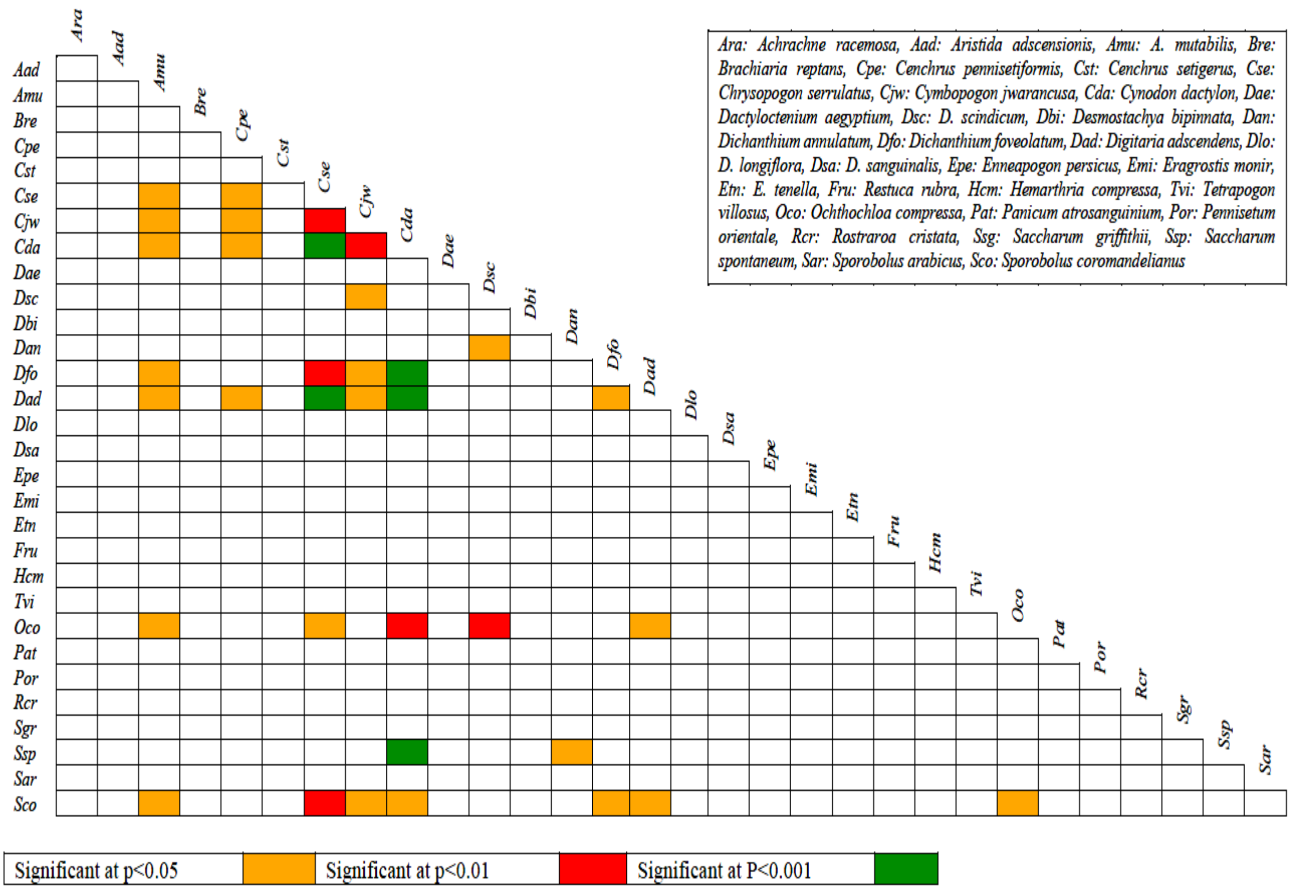

Fig. 4. Species association among grasses at 800 m a.s.l. in the Potohar region.

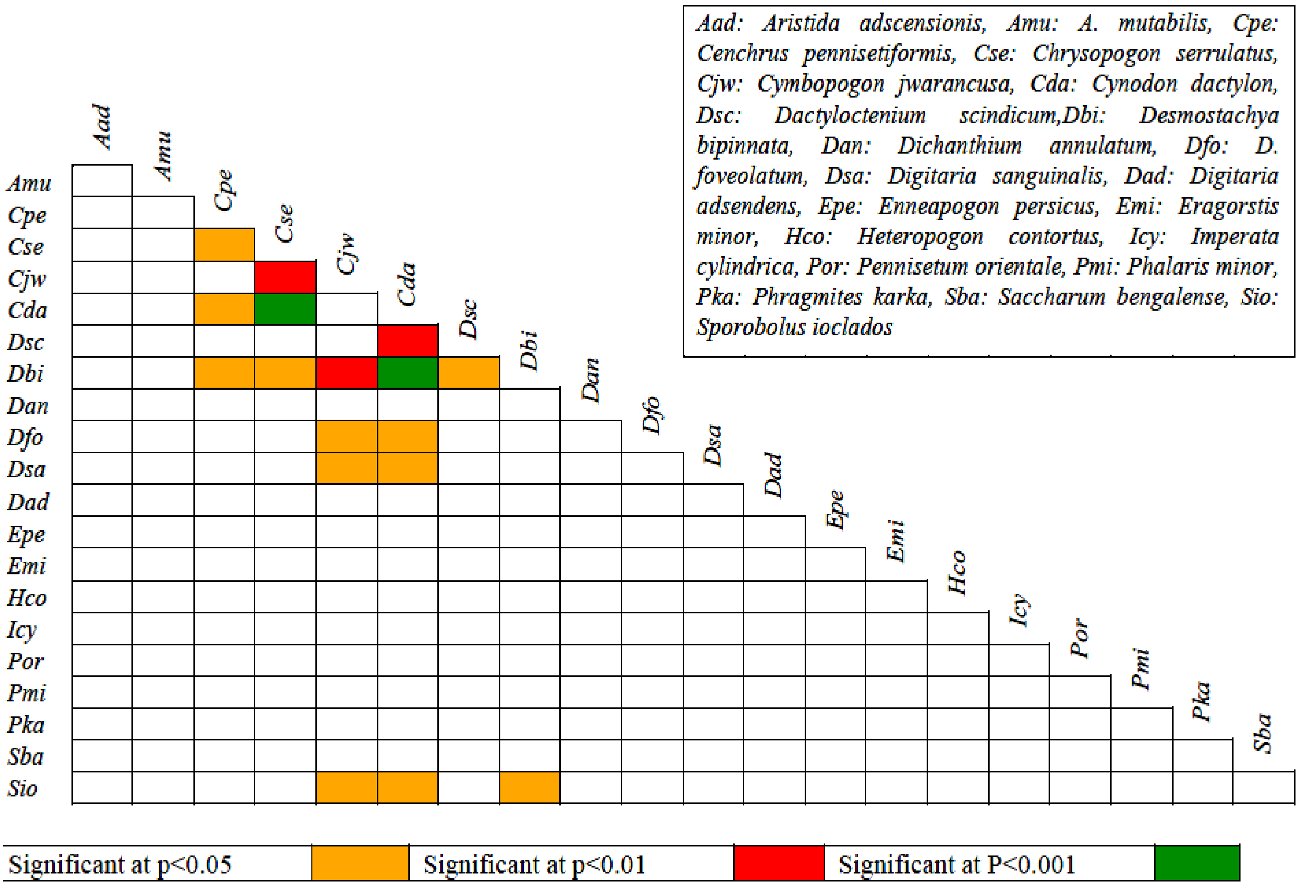

Fig. 5. Species association among grasses at 1000 m a.s.l. in the Potohar region.

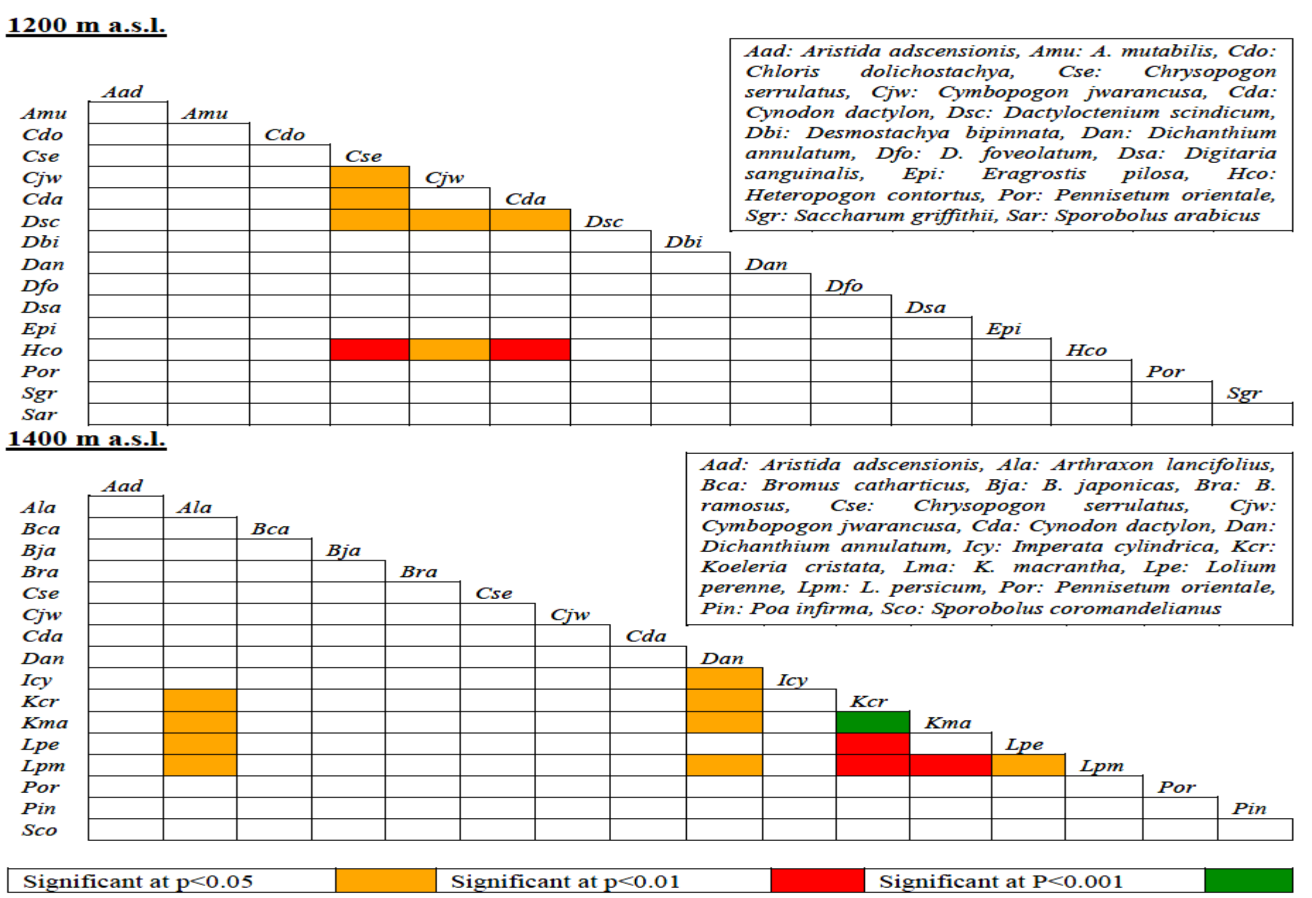

Fig. 6. Species association among grasses at 1200 and 1400 m a.s.l. in the Potohar region.

The most dominant *C. serrulatus* again showed close association with *C. dactylon* (at $p<0.001$) and *C. jwarancusa* (at p,0.01). *Cynodon dactylon* was associated with *D. bipinnata* at 0.001, and with *D. scindicum* and *C. jwarancusa* at $p<0.01$ (Fig. 5). Significant associations ($p<0.05$) was recorded for *C. pennisetiformis* with *C. serrulatus*, *C. dactylon* and *D. bipinnata*, and *C. jwarancusa* and *C. dactylon* with *D. foveolatum*, *D. sanguinalis* and *S. ioclados*. *Heteropogon contortus* was the only species that showed strong association ($p<0.01$) with *C. serrulatus* and *C. dactylon* at 1200 m a.s.l., but it also showed association with *C. jwarancusa* at $p<0.05$ (Fig. 6). *Dactyloctenium scindicum* was associated with three grasses (*C. serrulatus. C. jwarancusa* and *C. dactylon),* these three grasses shared major component of vegetation. *Chrysopogon serrulatus* also associated with *C. jwarancusa* and *C. dactylon.*

Vegetation composition was significantly different at 1400 m a.s.l., where the most dominant *K. cristata* strongly associated with *K. macrantha* at $p<0.001$ (Fig. 6), and with *L. perenne* and *L. persicum* at $p<0.01$. A strong association was also recorded for *K. macrantha* with *L. persicum* at $p<0.01$. All these species also showed association with *A. lancifolius* and *D. annulatum* at $p<0.05$.

Discussion

Species distributional pattern, species composition and community structure significantly altered with altitudinal gradient as reported by a number of researchers all over the world (Luo *et al*., 2004, Li *et al*., 2011; Abbasvand *et al*., 2014). Similar finding has been recorded in the Potohar region, particularly at higher altitudes. Variability in climatic and physiographic conditions are exceptionally high in the region, such as high mountain peaks of Tret, Daleh and Sakesar (c. 1500 m a.s.l.), sandy desert in Khushab district, heavily salt-affected foothills near Lillah and Pind Dadan Khan, vast valleys like Vanhar, Soone and Soan, protected areas like Chinji, Chunbi-Surla, Kala-Chitta hills, Lehri-Jindi and Domeli-Diljabba, drier hills of Kalabagh, cooler Murree foothills, etc. (Mahmood *et al.*, 2012). These variation is strong enough to impose a drastic change in distributional pattern and ecology of inhabitant grass species.

Species with wide distributional range can be linked to their potential of tolerance to environmental adversaries (Bijlsma & Loeschcke *et al.*, 2005). Species colonizing lower altitudes were different from those of higher altitudes in their structure, distributional range and contribution towards community structure (Lenoir *et al.*, 2008). High altitude species like *Lolium persicum, L. perenne, Themeda anathera, Arthraxon lancifolius, Apluda mutica, Rostraria cristata,* and *Koeleria cristata* and *K. macrantha* restrict to limited areas.

Vegetation of the Potohar region is constantly under threat due to anthropogenic activities like firewood collection, mining activities, construction work, overexploitation of medicinal/ economic plant resources, deforestation for agricultural purposes, habitat fragmentation, grazing and browsing of livestock (Wilson *et al.*, 2005). As a consequence, quite a few species are endangered, and facing extinction at local and international level (Nawaz *et al.*, 2012). It is, therefore, necessary to enlist grass species of the Potohar region in lines of distributional range and conservation status, which is important for a development of working plan for conservation of local plant resources.

Increase in elevation had a significant impact on grass species richness, association and distributional pattern in the Potohar region. Richness was the maximum at moderate elevation (600-800 m a.s.l.). This can be related to better growth condition, and climatic condition is not too harsh as recorded at foothills (mostly salt-affected) and mountain peaks (extremely cool temperature). Moreover, species like *H. contortus*, *A. adscensionis, D. scindicum* in addition to *C. serrulatus* and *C. jwarancusa* dominated the vegetation community, all these species are well-adapted to xeric conditions (Nawaz *et al.*, 2012). Species richness significantly reduced at higher altitudes, as climatic condition became more adverse as we moved upwards (Grytnes & Vetaas, 2002). Environmental conditions abruptly changed at the highest altitude regarding temperature, atmospheric pressure, amount of annual rainfall and nutrient availability (Adler & Levine, 2007). This change resulted in a complete change in grass community structure, xeric species were replaced by high altitude species that could resist cooler temperatures. Upward shift of species can also be related to change in climatic conditions at global scale, which is also a hot issue of recent times (Lenoir *et al*., 2008).

Lower altitudes of the Potohar region generally shared similar climatic conditions with few exceptions. This might be a strong reason for close association of two or three dominant species at almost all altitudinal ranges except at 1400 m a.s.l., where a sudden change in climates and vegetation observed. *Chrysopogon serrulatus, C. jwarancusa* and *C. dactylon* dominated the vegetation component all over the Potohar region, all showed significant association among themselves (Patterson, 1980). Species of aquatic habitats, *Saccharum spontanium,* and therefore, showed association with *Imperata cylindrica* or *Cynodon dactylon,* which also shared similar habitats, as reported by Chang *et al.* (2012).

It is concluded that association usually existed between dominant species that shared similar resources. Species colonizing moister habitats, saline patches, drier hills. mountain slopes, low temperature ranges and sandy clayey soils, all have strong associations. Domination of species almost similar up to 1200 m a.s.l., however, species composition changed significantly along altitudinal gradient.

Acknowledgement

This manuscript is a part of Ph.D. thesis of Sana Fatima, submitted to Department of Botany, University of Agriculture, Faisalabad.

References

Abbasvand, E., S. Hassannejad, J. Shafagh-Kolvanagh and S. Zehtab Salmasi. 2014. Altitude and soil properties affected grassland and weed distribution. *J. Biodiv. Environ. Sci*., 4: 231-235.

Adler, P.B. and J.M. Levine. 2007. Contrasting relationships between precipitation and species richness in space and time. *Oikos*, 116: 221-232.

Ahmad, I., M.S.A. Ahmad, M. Hussain, M. Ashraf, M.Y. Ashraf and M. Hameed. 2010. Spatiotemporal aspects of plant community structure in open scrub rangelands of submountainous Himalayan plateaus. *Pak. J. Bot*., 42: 3431-3440.

Bijlsma, R. and V. Loeschcke. 2005. Environmental stress, adaptation and evolution: an overview. *J. Evol. Biology*, 18: 744-749.

Bogenrieder, A. and R. Klein. 1982. Does solar UV influence competitive relationship in higher plants? In: (Ed.): Calkins, J. The role of solar ultraviolet radiation in marine ecosystems. Plenum Press, New York, pp. 641-649.

Chang, D., F.Y. Yang, J.J. Yan, Y.Q. Wu, S.Q. Bai, X.Z. Liang, Y.W. Zhang and Y.M. Gan. 2012. SRAP analysis of genetic diversity of nine native populations of wild sugarcane, *Saccharum spontaneum*, from Sichuan, China. *Gen. Mol. Res*., 11: 1245-53.

Charrier, G., M. Pramsohler, K. Charra-Vaskou, M. Saudreau, T. Ameglio, G. Neuner and S. Mayr. 2015. Ultrasonic emissions during ice nucleation and propagation in plant xylem. *New Phytologist*, 207: 570-578.

Chaudhry, A.A., M. Hameed, R. Ahmad and A. Hussain. 2001. Phytosiciology of Chhumbi-Surla wildlife sanctuary, Chakwal, Pakistan. I. Species Diversity. *Int. J. Agri. Biol*., 3: 363-368.

Greig-Smith, P. 1983. Quantitative plant ecology (Vol. 9). University of California Press.

Grytnes, J.A. and O.R. Vetaas. 2002. Species richness and altitude: a comparison between null models and interpolated plant species richness along the Himalayan altitudinal gradient, Nepal. *The American Naturalist*, 159: 294-304.

Hameed, M., N. Naz, M.S.A. Ahmad, Islam-ud-Din and A. Riaz. 2008. Morphological adaptations of some grasses from the Salt Range, Pakistan. *Pak. J. Bot*., 40: 1571-1578.

Hameed, M., T. Nawaz, M. Ashraf, F. Ahmad, K.S. Ahmad, M.S.A. Ahmad, S.H. Raza, M. Hussain and I. Ahmad. 2012. Floral biodiversity and conservation status of the himalayan foothill region, Punjab. *Pak. J. Bot*., 44: 143-149.

Hubálek, Z. 1982. Coefficients of association and similarity, based on binary (presence-absence) data: An evaluation. *Biol. Rev*., 57: 669-689.

Kofidis, G., A.M. Bosabalidis and M. Moustakas. 2003. Contemporary seasonal and altitudinal variations of leaf structural features in oregano (*Origanum vulgare* L.). *Ann. Bot.*, 92: 635-645.

Lenoir, J., J.C. Gegout, P.A. Marquet, P. De-Ruffray and H. Brisse. 2008. A significant upward shift in plant species optimum elevation during the 20th century. *Sci*., 320: 1768-71.

Li, L., M. Rutlin, V.E. Abraira, C. Cassidy, L. Kus, S. Gong, M.P. Jankowski, W. Luo, N. Heintz, H.R. Koerber, C.J. Woodbury and D.D. Ginty. 2011. The functional organization of cutaneous low-threshold mechanosensory neurons. *Cell*, 147: 1615-1627.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical ecology: a primer in methods and computing (Vol. 1). John Wiley & Sons.

Luo, T.X., Y. Pan, H. Ouyang, P. Shi, J. Luo, Z. Yu and Q. Lu. 2004. Leaf area index and net primary productivity along subtropical to alpine gradients in the Tibetan Plateau. *Global Ecol. Biogeogr.*, 13: 345-358.

Mahmood, T., R. Hussain, N. Irshad, F. Akrim and M.S. Nadeem. 2012. Illegal mass killing of Indian pangolin (*Manis crassicaudata*) in Potohar region, Pakistan. *Pak. J. Zool*., 44: 1457-61.

Nawaz, T., M. Hameed, M. Ashraf, F. Ahmad, M.S.A. Ahmad, M. Hussain, I. Ahmad, A. Younis and K.S. Ahmad. 2012. Diversity and conservation status of economically important flora of the Salt Range, Pakistan. *Pak. J. Bot*., 44: 203-211.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annu. Rev. Ecol. Syst*., 37: 637-669.

Patterson, D.T. 1980. Shading effects on growth and partitioning of plant biomass in cogongrass (*Imperatacylindrica*) from shaded and exposed habitats. *Weed Sci*., 28: 735-740.

Pauli, H., M. Gottfried, K. Reier, C. Klettner and G. Grabherr. 2007. Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994–2004) at the GLORIA mastersite Schrankogel, Tyrol, Austria. *Glob. Change Biol*., 13: 147-156

Rashid, K. and G. Rasul. 2011. Rainfall Variability and Maize Production over the Potohar Plateau of Pakistan. *Pak. J. Meteor*., 8: 63-74.

Vitasse, Y., A.J. Porté, A. Kremer, R. Michalet and S. Delzon. 2009. Responses of canopy duration to temperature changes in four temperate tree species: relative contributions of spring and autumn leaf phenology. *Oecologia*, 161: 187-198.

Wilson, K., R.L. Pressey, A. Newton, M. Burgman, H. Possingham and C. Weston. 2005. Measuring and incorporating vulnerability into conservation planning. *Environmental management*, 35: 527-43.

(Received for publication 22 February 2017)