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Classification and Compositional Differentiation of Alpine Grassland Vegetation of Gurez Valley, Kashmir

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ABSTRACT

Despite their ecological and cultural significance, the mountain grasslands of Kashmir Himalaya remain poorly studied. In this context, this study classifies the vegetation of high altitude grasslands of Gurez valley, Kashmir, with a focus on the influence of various environmental factors on the distribution of different vegetation groups. It also highlights the variation in the species distribution along an altitudinal gradient. Field data collected at 35 sites across three grasslands during 2008-2010 was analysed through TWINSPAN (Two way indicator of species analysis) and DCA (Detrended Correspondence Analysis). TWINSPAN classified the abundance data into nineteen plant associations that were confirmed by the application of DCA, albeit with some overlap. These associations could be clustered for three major vegetation groups that were closely linked to altitude and human disturbance. The highly disturbed plant associations were at lower altitudes and were less diverse as against the least disturbed higher elevated types that were largely stable but had a restricted distribution. In contrast, the mid-elevational plant associations showed a high internal variation and had many locally dominant species. The data generated will be helpful in providing an insight into the trends in vegetation dynamics, conservation status of various plant species besides being crucial to our understanding of biological diversity of this region as a whole.

Key words: Gurez valley, TWINSPAN, vegetation classification

INTRODUCTION

Recognising that categorizing plant communities not only provides floristic information of a region but also aids in their better management, plant communities have been classified and studied for their underlying patterns worldwide (Burke, 2002; Hussain *et al*., 2008). In high mountain ecosystems such studies are particularly important because as the species at higher altitudes have developed due to historic isolation or speciation (Churchill *et al*., 1995), their variation not only expresses the heterogeneity of diverse ecosystem processes but also helps in understanding an overall pattern of biodiversity. These also assist in determining the appropriateness of sites for establishing certain plant species. Of various methods used to investigate plant communities, numerical techniques have been used widely. These techniques provide means of evaluating a classification of plant communities and based on the dominance of few key indicator species enable detection of patterns (Jongman *et al*., 1995). These indicator species are considered as a distinguishing character of a community and therefore, any diminution of biodiversity is bound to change the community attributes. Among the commonly used techniques to determine these indicator species, TWINSPAN (Hill, 1979) ranks high (Barbour *et al.*, 1987) and at present is possibly the most frequently used procedure for the classification of community data sets.

For ecosystem evaluation, species diversity is one of the most important indices, with variations in it being linked to several ecological gradients (Palmer, 1992). Among different gradients, altitude is of high importance and is considered to be most decisive in shaping the spatial patterns of species diversity (DeBano and Schmidt, 1990; Lomolino, 2001). Effects of altitude on species diversity have been the subject of many ecological studies in recent years. Many studies have reported that diversity peaks at intermediate elevations and proposed the commonly known hump-shaped pattern (Stevens, 1992; Pausas, 1994) but still there are exceptions and thus for a more general theory of describing species diversity along an elevational gradient, workers have cautioned to use more standardized measurements of environmental variables and minimising sampling biases (Lomolino, 2001; Brown, 2001). This is more so important in many mountainous areas like Kashmir Himalaya wherein the broad species diversity patterns governed by altitude are superimposed by livestock grazing.

Past studies of grassland ecosystems in Kashmir valley have mostly focused on their systematics and vegetation accounts (Bhat *et al.*, 2002), species variation along elevational gradient (Reshi *et al.*, 2009), pastoralism vis-a-vis grassland biodiversity (Rao and Casimir, 1985) and grassland degradation (Shah, 1991). It is only recently that there have been a few systematic sampling studies that have both classified and studied the ecological relations for mountain vegetation in Kashmir Himalaya (Dvorsky *et al.*, 2011). However, given the developmental rapidity and changing socio-political arrangement and grazing practices which have initiated an unprecedented disturbance and affected the vegetation enormously, such studies are to be taken at a broad spatial scale. In this context, present study was carried on few mountain grasslands of Gurez valley, Kashmir with a prime objective to classify the vegetation by employing multivariate techniques. We also aim to study the variation in species diversity along an elevational gradient and establish distribution pattern of various species and degree of similarity between different sites and associations and identify their key indicator species.

MATERIALS AND METHODS

Study area: The studied area is at the extreme tip of Kashmir Himalaya in the mountainous region of Gurez valley (34°30'-34°41' N and 74°37'-74°55' E) Kashmir, India. Owing to the contrasting topographical and climatic gradients, vegetation patterns of the valley change sharply and display a mosaic of patches of forests, shrublands and grasslands. The climate of valley is temperate with four usual seasons and a low mean annual temperature compared to surrounding plains.

Field methods: Field surveys were conducted at three mountainous grasslands viz. Minimarg (34°33' N; 74° 53'E; Alt. 3058-4250), Patalwan (34°31'N; 74°51' E; Alt. 3190-4428) and Viji (34°34'N; 74°45'E; Alt. 3468-4170) between the snow free months from late May to early November, during 2008-2010. At these grasslands, 35 sites (11 at Viji and 12 each at Minimarg and Patalwan) that represented various habitat types were selected and sampled by randomized systematic sampling method. Quadrat size -0.25 m^2 (50×50 cm) for herbs and 25 m^2 (5×5 m) for shrubby patches and number (n = 35) for each site was determined using the species area curve and running mean method (Misra, 1968; Mueller-Dombois and Ellenberg, 1974).

Data analysis methods: Floristic list, number and cover (%) of each vascular plant were determined in each quadrat. The number, frequency and cover was summed as Importance Values Index (IVI), changed into percentages and then used in correspondence analysis. To derive associations of vegetation based on their floristic composition, sampled plots were first pooled and then put into a sample by species data matrix and then classified into vegetation types using the polythetic divisive classification of the two way indicator species analysis-TWINSPAN programme (Hill, 1979). The floristic data matrix consists of 1225 quadrat plots and 232 plant species, collected across 35 sites. To overcome variance, data was first transformed to percentages and then cut levels were selected to choose pseudo-species. The analyses were run using default options with five cut-off levels (0, 2, 5, 10 and 20) for pseudo-species. A hierarchical classification of vegetation was obtained in a table form and results were presented in unscaled dendrogram. Detrended Correspondence Analysis (DCA), a reciprocal ordination technique that simultaneously ranks plots and species based on the similarities of species composition and on the plots in which they occur was applied to confirm phytosociological units. It is an indirect ordination technique whereby environmental gradients are discerned from the species data based on the assumption that species co-vary in a systematic fashion, for they are responding to the same underlying environmental gradient. For each association, diversity was studied by its species richness-S and Shannon-Wiener Index-H' (Shannon and Weaver, 1949) while evenness was calculated by Hurlbert's Probability of Intraspecific Encounter –PIE (Hurlbert, 1971). To explore differences at lowest level, all indices were calculated at individual quadrat level and averaged as richness (S_{avg}), diversity (H'_{avg}) and evenness (PIE_{avg}) for a community. One way analysis of variance(ANOVA) was used to test observed differences (Zar, 1984).

RESULTS

Species composition and richness: A total of 232 plant species from 44 families and 147 genera were recorded from the sampled grasslands, with four species viz. *Arabis nova* Vill, *Thlaspi coclearioides* Hook.f and Thomas, *Gentiana venusta* Wall. ex Griseb and *Primula involucrata* Wall.ex Dubey qualifying as newly recorded distributions for Gurez valley. At lower elevations, tall herbaceous species are more conspicuous and include *Heracleum candicans* Wall. ex DC., *Chaerophyllum acuminatum* Lindl. and *Seseli libanotiss* (L.) Koch. However, on scree, snow melt and glacial moraines, plants mostly found are rosettes and small stemmed and include mostly *Corydalis crassifolia* Royle, *Gentiana moorcroftiana* Wall. ex G. Don, *G. venusta* Wall. ex Griseb., *G. tianschanica* Rupr. ex Kusn, *Pseudomertensia moltkioides* (Royle ex Benth.) Kazmi. and *Scutellaria prostrata* Jacq. ex Benth. The shrubby elements recorded a little representation and include *Juniperus wallichiana* Wall, *Rhododendron anthopogan* D.Don and *Cassiope fastigiata* (Wall.) D.Don while *Thymus linearis* Benth. and *Sambucus wightiana* Wall ex Wt and Arn are other semi shrubs that occur mostly on dry instable and over grazed slopes. The graminoid category is represented mostly by the members from Poaceae, Cyperacea and Juncaceae and includes species like *Poa annua* L., *P. bulbosa* L., *Stipa sibirica* L., *Juncus thomsonii* Buchen and *Dactylis glomerata* L., *Osmunda claytoniana* L. is the most frequent fern species found across all these grasslands.

The species richness varied greatly with a large portion of species being rare or infrequent. Among quadrats the species richness ranged from 1-19 species with an average of 7.38 species per quadrat while among the sites, it was also significantly different and ranged from 15-49 species with an average 29 species per site. Between the species on a percent basis, *Sibbaldia cuneata* Hornem. ex Kuntze (16.02), *Lagotis cashmeriana* (Royle) Rupr. (5.36), *P. annua* (5.11) and *Geum urbanum* L. (3.76) had the highest importance value index values and were more dominant across numerous habitat types.Plotting the importance value index of these species along an elevational gradient showed that *S. cun*neata had a much wider distribution while *L. cashmeriana* was found mostly at higher altitudes. Among the grasses, *P. annua* recorded an initial dominance but at higher altitudes, it was least dominant (Fig. 1).

Vegetation classification: TWINSPAN was performed for vegetational analysis in 1225 quadrat plots. The results showed that at first dichotomy TWINSPAN classified the vegetation data into two main types ($\lambda = 0.620$) and from a mosaic of a broader plant group separated the high altitude plant associations with *L. cashmeriana* and *G. urbanum* as positive and *Fragaria nubicola* Lindl. ex Lacaita and *Trifolium repens* L. as negative indicators respectively. At first dichotomy, the separation of the higher alpine plant associations on the right side of the dendrogram together with the distribution pattern of its indicator species, therefore, highlighted the altitudinal variation in the data set. The two groups were divided further and till six splitting dichotomies according to the TWINSPAN table and eigen value of each division, the vegetation of the study area was separated into forty one TWINSPAN terminal groups that represented nineteen plant associations (Fig. 2). However, there were only few TWINSPAN clusters that had a single characteristic species which based on their percent frequency classes could completely separate these associations while the others had three to four species. Six clusters were dominated by a single species (1, 3, 5, 15, 16 and

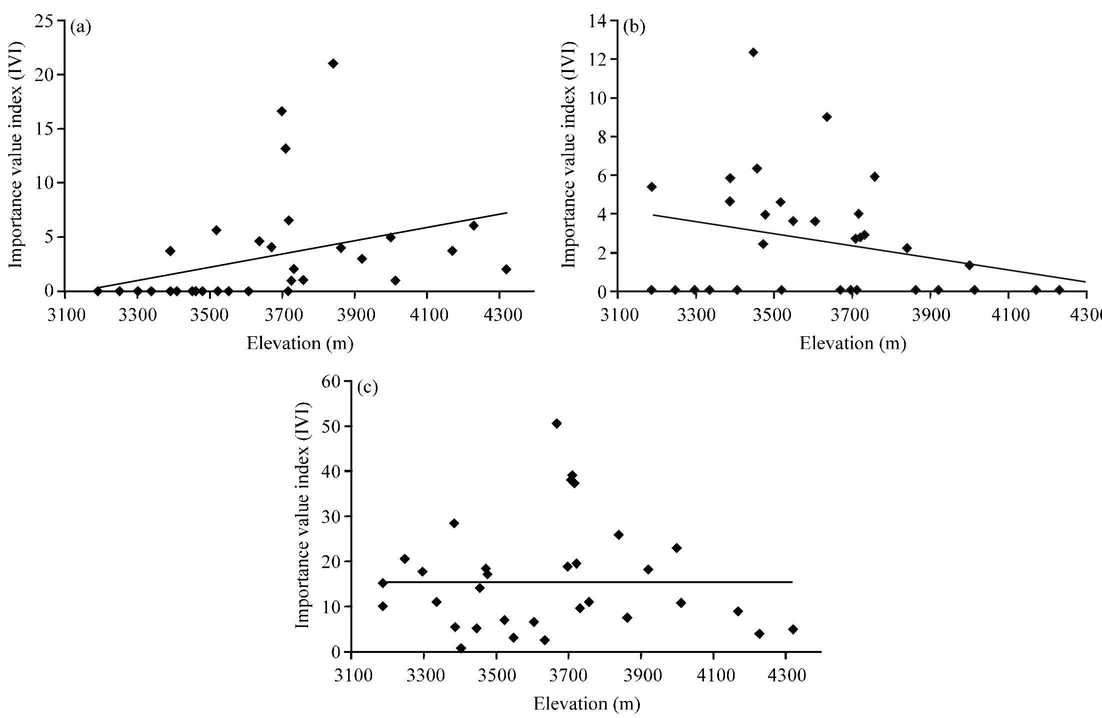

Fig. 1(a-c): Importance Value Index (IVI) of three dominant species viz. *Lagotis cashmeriana* (a), *Poa annua* (b) and *Sibbaldia cuneata* and (c) plotted against altitude

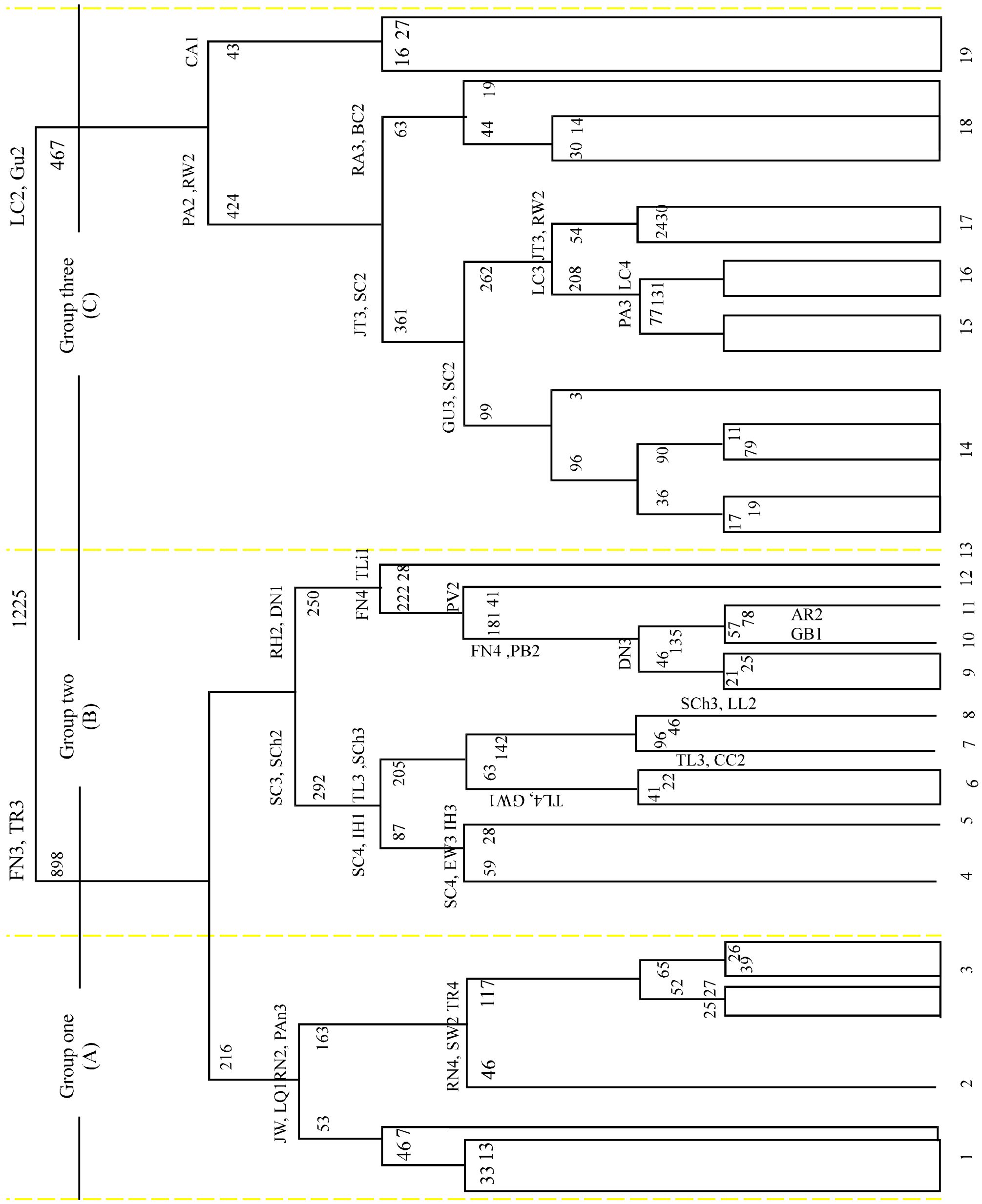

Fig. 2: Un-scaled TWINSPAN dendrogram of 1225 quadrats at three grasslands of Gurez valley Kashmir. Number codes, plant associations and three main groups drawn with dotted lines are described in text. Indicator species and their pseudo-species cut levels are indicated by following abbreviations. LA: *Lagotis cashmeriana*, PA: *Polygonum affine*, SC: *Sibbaldia cuneata*, RH: *Ranunculus hirtellus*, TR: *Trifolium repens*, SCh: *Senecio chrysanthemoides*, IH: *Iris hookeriana*, JT: *Juncus thomsonii*, RW: *Rhodiola wallichiana*, RN: *Rumex nepalensis*, SW: *Sambucus wightiana*, PAn: *Poa annua*, TR: *Trifolium repens*, CA: *Caltha alba*, GU: *Geum urbanum*, TL: *Tanaceteum longifolium*, JW: *Juniperus wallichiana*, PB: *Phlomis bracteosa*, TLi: *Thymus linearis*, BC: *Bergenia ciliata*, PV: *Polygonatum verticillatum*, *EL: Elymus long-earistatus*

19), of which three were restricted to the lower altitudes while the rest were characteristic of higher alpines. No species was recorded in all associations. But yet largely determined by altitude, habitat type and anthropogenic disturbance, these associations could be merged into three broad vegetation groups that differed both in terms of their environmental needs, species composition and abundance. The distribution, description, indicator species and diversity and density of each of these three broad groups are summarised in Table 1. A brief description of these three vegetation groups is given under:

Group A: Represented by the TWINSPAN clusters 1-5, this group represent the lower altitude (<3400 m) plant associations having a lower species richness than the others. It includes plant assemblages that are grazed for relatively longer periods. Because of high and prolonged biotic pressure, the accompanying associations have a high number of ruderal species and thus characterize mostly the overgrazed surfaces and landmasses close to camping sites, animal dwellings and human settlements. Depending on the degree of anthropogenic disturbance various sub-units are evident wherein graminoids and forbs are fairly constant with the broad shrubby patches of *J. wallichiana* also scattered in a thin fashion. Notable species of this group include *Rumex nepalensis* Spreng., *S. wightiana*, *Polygonum aviculare* L. and *Malva neglecta* Wall. A high variation in average species density (350.96±303.22 individuals/m^2) of this group indicated that most of the accompanying species followed a non random distribution pattern.

Group B: This group was most evident at mid altitudes (3400-3750 m) and included many plant associations (6-15) that were dominant only at a smaller spatial scale and often not clearly differentiated due to a high internal variation. Among the three groups, the plant assemblages of this group are found in most of the places across the entire geographical range of this study. The broad habitat type of this group is generally a mix of open dry and unstable landmasses and soil surfaces with a fair proportion of rock, boulder and stony slopes. Characterized by a high species intermix, important species of this group include *Euphorbia wallichii* Hook f., *Iris hookeriana* Foster, *Tanaceteum longifolium* Wall.ex DC, *Ranunculus hirtellus* Royle ex D.Don, *Lindelofia longiflora* (Benth.) Baill, *Achillea millefolium* L, *Rumex acetosa* L and *Rosa webbiana* Wall. ex Royle. However among these all, *T. longifolium*-a cushion and a sprawling forb, is more prominent whereas *I. hookeriana* is distinguishable by its vivid appearance. The cover of the shrubs is relatively higher than the preceding group which is chiefly used by nomads as source of fuel wood. Towards the higher elevations on mid hilltops, scree slopes and other crags, the occurrence of *Valeriana hardwickii* Wall, *Meconopsis latifolia* (Pr.) Prain, *Rheum webbiana* Royle, *Fritillaria roylei* Hook and *Actaea spicata* L add to the conservation value of this group. Mean plant density of the group was recorded at 334.13±166.25 ind m^{-2}.

Group C: This group includes a broad category of ecologically differentiated plant associations that are linked to gentle level slopes and surfaces located at most remote, isolated and relatively protected; at altitudes above 3700 m. This group separates from the other two on account of its high forage quality, good feed value and a relatively high abundance of forbs with sporadic presence of rushes and sedges. The general habitat is free from rocky patches and boulders except for *Polygonum affine* D.Don which at lower altitudes is found growing gregariously in voids between boulders, foot of large rocks, cliffs and stony plains. Generally, the graminoids are in low abundance whereas other forbs are abundant. On irregular bouldery and rocky surfaces

Table 1: Summary of the different vegetation groups at Gurez valley, Kashmir

Clnster (Group)	TWINSPAN end group	Total quadrats	Indicator species	Brief location	Diversity: Macro level-Group basis H'	PIE	S	Micro level-Quadrat basis H'	PIE	S	Density (Ind/m^2)
A	1-5	216	RN, SW, PA, TR	Flatlands, abandoned camping sites and heavily grazed surfaces	2.25	0.78	58	1.24±0.41	0.60±0.19	6.42±2.22	450.96±353.2
B	6-14	542	FN, SC, EW, TL	Low moderate slopes, undulating plaims and highly elevated human and animal trail between 3400-3700 m	2.69	0.82	78	1.39±0.31	0.64±0.16	7.25±2.08	334.13±266.2
C	15-19	467	PA_F, LC, GU, RW	Open exposed tablelands and gentle surfaces and mountain ridges at altitudes >3700 m	2.47	0.81	61	1.33±0.42	0.63±0.17	6.71±1.93	338.01±202.9

RN: *Rumex nepalensis*, SW: *Sambucus wightiana*, PA: *Poa annua*, TR: *Trifolium repens*, FN: *Fragaria nubicola*, SC: *Sibbaldia cuneata*, EW: *Euphorbia wallichii*, TL: *Tanaceteum longifolium*, PA_F,: *Polygonum affine*, LC: *Lagotis cashmeriana*, GU: *Geum urbanum*, RW: *Rhodiola wallichiana*, H': Shannon wiener index, PIE: Evenness Index, S: Species richness

R. anthopogan and *C. fastigiata* forms a characteristic layer, with both relatively low in stature. However, *R. anthopogan* slightly dominates over *C. fastigiata* and contribute fairly to the vegetation cover. On flat and smooth surfaces and gentle rolling tablelands, *L. cashmeriana* is widespread with *C. crassifolia*, *G. moorcroftiana*, *G. venusta*, *G. tianschanica*, *P. moltkioides, Delphenium cashmerianum* Royle, *Callianthemum pimpinelloides* (D. Don ex Royle) Hook.f. and Thom, *Trollius acaulis* Lindl and *Phleum alpinum* L. *Thlaspi coclearioides* Hook. f. and Thoms is an important differential species while *Picrorhiza kurroa* Royle ex Benth is less frequent. On water logged, poorly drained depressions and other smaller alpine bogs *Rhodiola wallichiana* (Hook) Fu and *J. thomsonii* are also evident while on scree, snow melt and glacial moraines, rosette formations and other small stemmed plants are evident. The average density of this group, on a meter scale, was recorded at 338.04±202.91 ind m^{-2}.

Ordination of vegetation groups: Supporting the TWINSPAN divisions, the ordination analysis carried by employing DCA (Detrended Correspondance Analysis) effectively separated the three broad groups albeit the groups formed tight clusters with some degree of overlapping (Fig. 3). The overlapping was more apparent for lower and mid altitudinal groups that were characterized by a high internal spatial variation. The horizontal axis (λ = 0.366) of the diagram reflects the variation in topography and corresponds to the altitudinal gradient. This is also evident by the separation of the group C which clustered in the right side of the DCA ordination. However, the vertical axis (λ = 0.652) reflects the decisiveness of the anthropogenic disturbance and clusters group A to upper extreme left of axis 1 (λ = 0.652), that suggests that its occurrence is more towards the lower elevated but highly disturbed sites. Supportive of the TWINSPAN analyses, the plots from the group B, belonging to the middle elevations are clustered between A and C and thus

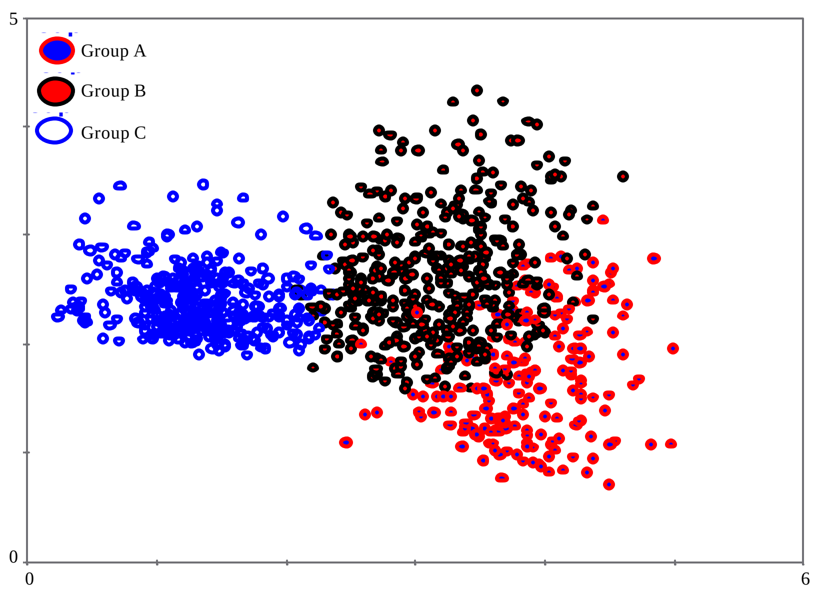

Fig. 3: Ordination diagram from detrended correspondence analysis (DCA) method, applied to 1225 quadrat plots from the three surveyed grasslands at Gurez valley, Kashmir. Axes 1 and 2 are shown, explaining 53% of compositional variation

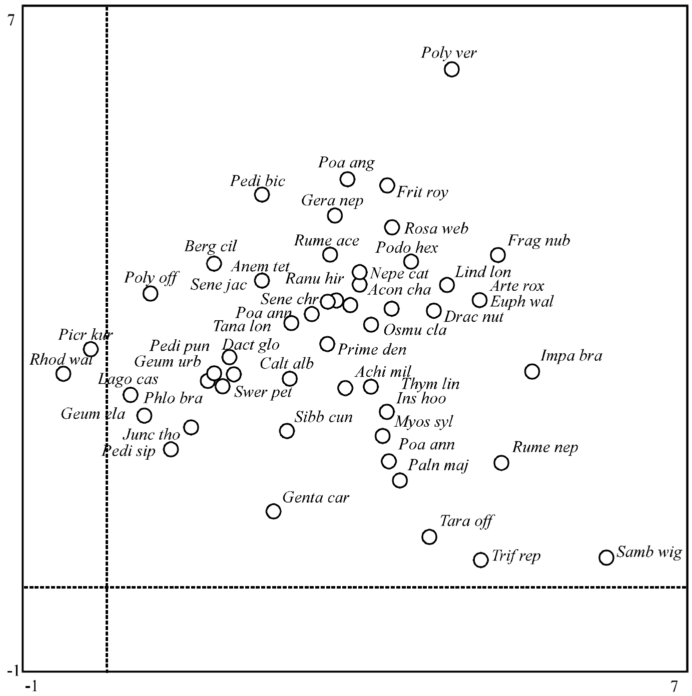

Fig. 4: Ordination diagram from the DCA method, applied to all the 232 plant species. Axes 1 and 2 are shown, explaining 23% of the compositional variation. Species are coded as *Gera nep*: *Geranium nepalensis, Ploy ver*: *Polygonatum verticillatum, Rume ace*: *Rumex acetosa, Pedi bic*: *Pedicularis bicornuta, Phlo bra*: *Phlomis bracteosa, Ranu hir*: *Ranunculus hirtellus, Frag nub*: *Fragaria nubicola, Podo* hex: *Podophyllum hexandrum,* Poa ang: *Poa angustifolia, Lind lon*: *Lindelofia longiflora, Euph wal*: *Euphorbia wallichii, Arte rox*: *Artemisia roxburghiana, Achi mil*: *Achillea millefolium, Drac nut*: *Dracocephalum nutans, Sene chr*: *Senecio chrysanthemoides, Thym lin*: *Thymus linearis, Iris hoo*: *Iris hookeriana, Myos syl*: *Myosotis sylvatica, Poa ann*: *Poa annua, Plan maj*: *Plantago major, Gent car*: *Gentiana carinata, Tara off*: *Taraxicum officinale, Samb wig*: *Sambucus wightiana, Rume nep*: *Rumex nepalensis, Impa bra*: *Impatiens brachycentra, Ploy aff*: *Polygonum affine, Rhod wal*: *Rhodiola wallichiana, Lago cas*: *Lagotis cashmeriana, Geum ela*: *Geum elatum, Junc tho*: *Juncus thomsonii, Geum urb*: *Geum urbanum, Pedi pun*: *Pedicularis punctata, Swer pet*: *Swertia petiolata, Tana lon*: *Tanaceteum longiflora, Sibb cun*: *Sibbaldia cuneata, Trif rep*: *Trifolium repens, Frit roy*: *Fritillaria roylei, Rosa web*: *Rosa webbiana, Nepe cat*: *Nepeta cataria, Acon cha*: *Aconitum chasmanthum, Osmu cla*: *Osmunda claytoniana, Pedi sip*: *Pedicularis siphonantha, Calt alb*: *Caltha alba, Dact glo*: *Dactylis glomerata, Prim den*: *Primula denticulata, Anem tet*: *Anemone tetresepala, Sene jac*: *Senecio jacquemontiana, Picr kur*: *Picrorhiza kurrooa,* Berg cil: *Bergenia ciliata.* (Only the most dominant species are shown)

appear as transitional between these two groups. However a high intermixing between group A and B is also evident which suggests a possible gradual shift in this transition.

Ordination of species: The ordination diagram of individual species is presented in Fig. 4. As is evident, several forbs together with the other nitrophilic species like *R. nepalensis*, *S. wightiana*

Table 2: Species richness, diversity and evenness (Mean±SD) in various strata

		Scale of measurement					
		Macro (stand basis)			Micro (quadrat basis)		
Strata	No. of stands	S	H'	PIE	S	H'	PIE
Sub-alpine	14	25.18±7.2	2.06±0.4	0.70±0.1	6.78±1.0	1.25±0.1	0.60±0.1
Lower alpine	13	31.00±7.2	2.36±0.4	0.81±0.1	7.21±1.3	1.35±0.2	0.62±0.1
Higher alpine	8	29.77±6.9	2.20±0.6	0.74±0.2	6.44±1.6	1.26±0.3	0.61±0.2

S: Richness, H': Diversity, PIE: Evenness

and *P. aviculare* scored within the lower right side of the ordination space. The presence of these species is indicative of the nutrient rich and highly grazed and disturbed sites. Such an occurrence contrasts well with the species characteristic of high altitude and low disturbed sites such as *L. cashmeriana*, *R. anthopogon*, *C. fastigiata*, *P. affine* and *R. wallichiana* that are located in the upper right of the plot. However, a majority of other locally dominant species such as *R. hirtellus*, *Rumex acetosa* L., *I. hookeriana*, *T. longifolium*, *Primula denticulata* Smith and *Senecio chrysanthemoides* DC that are fairly common at middle elevations are grouped closely in the middle of diagram.

Diversity of vegetation groups: As a whole the species diversity (H'), richness (S) and evenness (PIE) did not indicate any major difference between groups. On a macro-scale (group basis), the most diverse group in terms of its richness (S = 7.25±2.08), diversity (H' = 1.39±0.39) and evenness (PIE = 0.64±0.16) was B followed by group C while group A was the least diverse. On lowering the scale and measuring the same parameters on a macro-scale (quadrat basis) did not produce any different results. Analysis of variance (ANOVA) showed that observed differences were statistically significant between richness (F = 16.29, F_{cric} = 1.59, p<0.01), diversity (F = 19.03, F_{cric} = 1.59, p<0.01) and evenness (F = 14.96, F_{cric} = 1.59, p<0.01) at both scales of measurement.

Variation in diversity along elevational gradient: Regardless of the vegetation groups, trends in diversity parameters were also studied by dividing sites into three primary strata viz sub-alpine (<3500 m), lower alpine (3500-3700 m) and higher alpine (>3700 m). On a site basis (macro-scale), the highest species richness (S = 31.00±7.2), evenness (PIE = 0.81±0.1) and diversity (H' = 2.36±0.4) was found in the lower alpine zone followed by the higher alpine zone (S = 29.77±6.9; PIE = 0.74±0.2 and H' = 2.20±0.6) while the lowest values were observed in sub alpine zone (S = 25.18±7.2; PIE = 0.70±0.1 and H' = 2.06±0.4). However, on a quadrat basis (micro-scale), the pattern of richness differed greatly and was highest in the lower alpine zone (S = 7.21±1.3) followed by sub-alpine zone (S = 6.78±1.0) while the higher alpine zone had the lowest richness (S = 6.44±1.6). On the same scale of measurement, while the lower alpine zone recorded the highest diversity (H' = 1.35±0.2), the other two strata were almost equally diverse (Table 2).

DISCUSSION

The floristic composition of the studied area is a mosaic of different life forms that correspond to a definite habitat type across different elevation belts. However among these life forms orchids were represented by only a mono species of *Dactylorhiza hatagirea* D.Don. This low representation could be due to lack of a definite tree life-form in these grasslands, as most of the west Himalayan orchids are epiphytic. Of all the sampled species, *S. cuneata* is the most ubiquitous; indicating its wide range of ecological amplitude (Ge *et al*., 2005). *S. cuneata* adapts to grazing by growing very close to the ground and creeps rapidly by forming extensive colonies wherein each of its cushions represents one genet. Because of these features, it has been reported as a dominant species in the other west Himalayan grasslands also (Shaheen *et al*., 2011). On an altitudinal gradient, species distribution showed a high heterogeneity and profound disparity relative to grassland location. This compositional complementarity highlights both the patchiness and rareness of species at a local level as well as a non uniformity of different environmental variables. Similar results have been reported in the grassland ecosystems of Dachigam National park, Kashmir (Reshi *et al*., 2009). At higher altitudes such a distribution pattern has been attributed to availability of nutrients and response to severe climatic conditions (Kikvidze *et al*., 2005). The eigenvalue at which first division (λ = 0.620) occurred indicated that the overall vegetation is heterogeneous while at subsequent divisions there is a considerable homogeneity. The present study revealed that except for few associations which were separated by a single characteristic species, there were not many discrete associations. But still on comparing our TWINSPAN results with other studies it becomes evident that many of our recorded plant associations have their analogues in the other alpine pastures like Pakistan (Shaheen *et al*., 2011). Differentiating the species into different communities highlights the habitat and landform diversity of the studied area and its importance in growing different plant types. However, condensing these plant associations into only three clusters (Table 1) is essentially oversimplifying their characteristics. But nonetheless, based on these clusters it appeared that group A is more dynamic, localized and highly disturbed as its TWINSPAN clusters are dominated by many unpalatable and nitrophilic species, including *R. nepalensis* and *S. wightiana* which is indicative of the high grazing pressure in these areas. However group B occupies the mid altitudes and is characterized by plant associations that lacked a strong vegetational contrast and recorded a high internal variation and intermixing of accompanying species. Such continuity in plant associations at middle altitudes has been reported for other Himalayan grasslands (Kala and Uniyal, 1999). In contrast, group C occurring at higher altitudes appeared as more stable and included many rare and threatened herbs, including *C. crassifolia, G. moorcroftiana, G. venusta, G. tianschanica, P. moltkioides* and *D. cashmerianum*.

The application of DCA supported the TWINSPAN divisions and confirmed the existence of different groups. But because only few differential species were found in this study, the quadrats with a similar species composition grouped together which added to an overlap and suggested that the distinctness of different associations is based not merely on their floristic differences alone but on the relative proportions of species in their respective groups also (Fig. 5). Such a situation is analytic of problems encountered when classifying the grazed plant associations because being continuous in nature; such associations are characterized by a gradual change of species composition. Nevertheless, identified indicator species for each of community can be used as snapshots for a precious ecological information and vegetation status of alpine flora of this valley.

At both measurement scales, a greater diversity recorded for group B is in agreement with Rawat (2007) who also reported that the diversity of alpine plants in Western Himalaya is highest between 3600-3800 m. On an overall basis, the species diversity compares well and is in fact higher than in other grazing ecosystems like Khag valley, Pakistan (H' = 2.89 to 3.33) (Shaheen *et al*., 2011). These comparable measurements reveal that anthropogenic disturbance did not seem to affect the richness and diversity as profoundly as it affects the structural variability of these

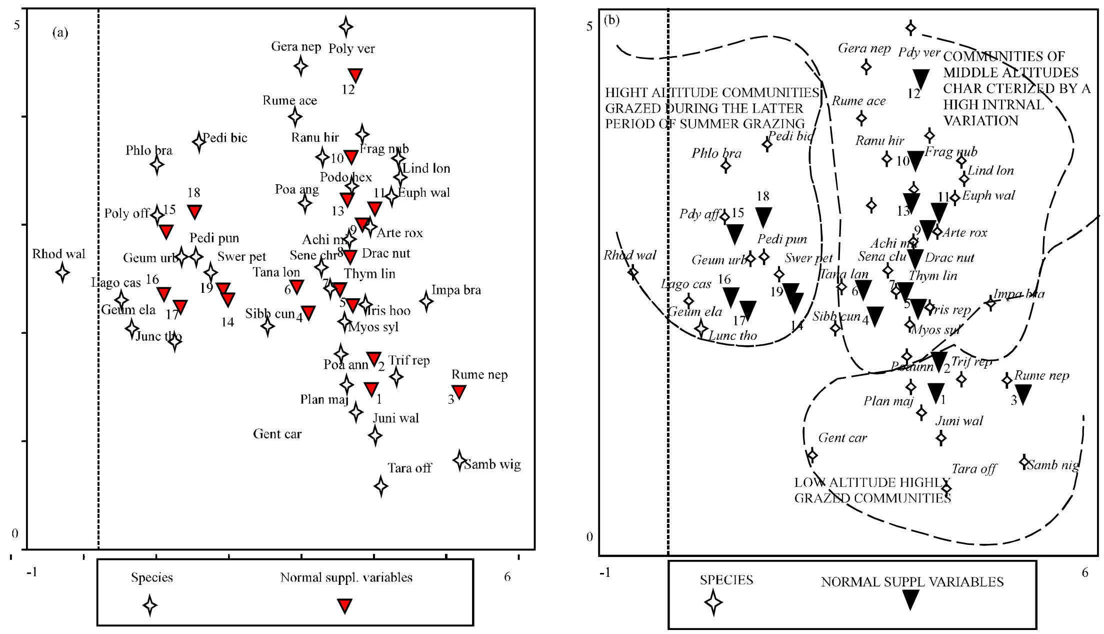

Fig. 5(a-b): Ordination plot displaying centroids of nineteen plant associations. Part a and b are given separately to facilitate the interpretation. Species are coded as *Gera nep*: *Geranium nepalensis, Ploy ver*: *Polygonatum verticillatum, Rume ace*: *Rumex acetosa, Pedi bic*: *Pedicularis bicornuta, Phlo bra*: *Phlomis bracteosa, Ranu hir*: *Ranunculus hirtellus, Frag nub*: *Fragaria nubicola, Podo hex*: *Podophyllum hexandrum, Poa ang*: *Poa angustifolia, Lind lon*: *Lindelofia longiflora, Euph wal*: *Euphorbia wallichii, Arte rox*: *Artemisia roxburghiana, Achi mil*: *Achillea millefolium, Drac nut*: *Dracocephalum nutans, Sene chr*: *Senecio chrysanthemoides, Thym lin*: *Thymus linearis, Iris hoo*: *Iris hookeriana, Myos syl*: *Myosotis sylvatica, Poa ann*: *Poa annua, Plan maj*: *Plantago major, Gent car*: *Gentiana carinata, Tara off*: *Taraxicum officinale, Samb wig*: *Sambucus wightiana, Rume nep*: *Rumex nepalensis, Impa bra*: *Impatiens brachycentra, Ploy aff*: *Polygonum affine, Rhod wal*: *Rhodiola wallichiana, Lago cas*: *Lagotis cashmeriana, Geum ela*: *Geum elatum, Junc tho*: *Juncus thomsonii, Geum urb*: *Geum urbanum, Pedi pun*: *Pedicularis punctata, Swer pet*: *Swertia petiolata, Tana lon*: *Tanaceteum longiflora, Sibb cun*: *Sibbaldia cuneata, Trif rep*: *Trifolium repens*

grasslands. Previous studies have also reported that high intensity of anthropogenic disturbances disturbs the natural balance of fragile alpine vegetation communities and prevents them from reaching a climax stage of community maturity (Saxena and Singh, 1982).

On an altitudinal gradient both species richness and diversity showed a gradual change (Fig. 6) and although it was relatively difficult to separate a single altitudinal belt where the change was more profound but yet the values were lowest initially, peaked in middle and decreased thereafter. Moreover most evident across both measurement scales was the sharp decrease in richness, diversity and evenness particularly between 3800-4000 m. Similar results have also been reported for Valley of Flowers National Park Valley (Kala and Uniyal, 1999). This because mid altitudinal ranges favour the co-existence of species common to both low and highaltitudinal

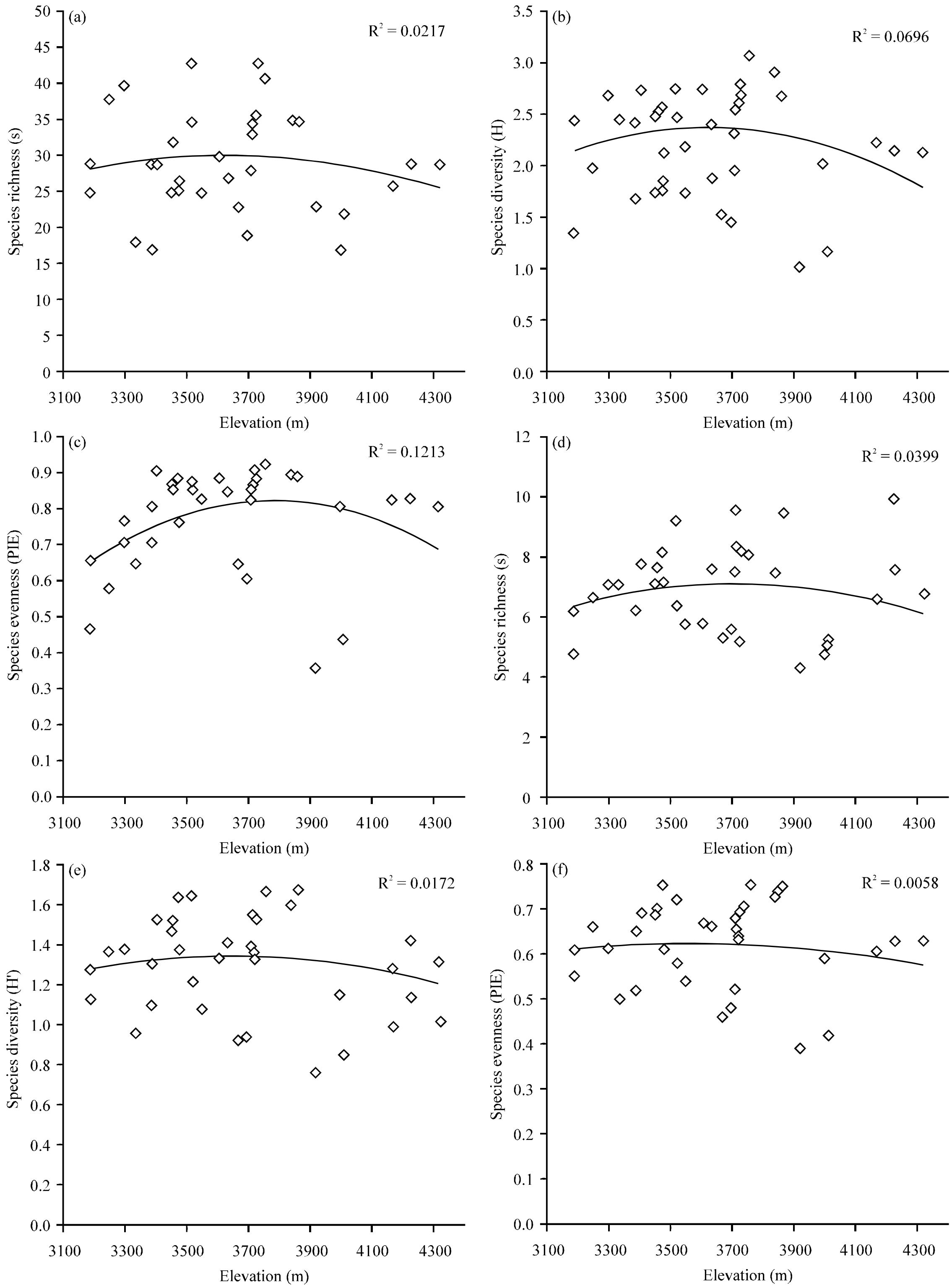

Fig. 6(a-f): Site data on a macro-scale (a, b and c) and micro-scale (d, e and f), plotted respectively against the elevations to show the variations of species richness (S), Shannon-Wiener's index of diversity (H') and Evenness (PIE) along an elevational gradient in the study area ranges (Lomolino, 2001) and thus increase the species richness. Moreover, compared to higher elevations, the lower altitude sites are grazed for relatively longer periods besides it also houses most camping sites and other human settlements which affect its species richness. Similarly on a lower scale of measurement, except for evenness wherein no noticeable trend along altitude was found, a similar pattern is observed. Thus essentially, our findings also re-confirm an intermediate pattern of species diversity-elevation relation. In summary, our results of the classification and ordination described the compositional patterns of vegetation groups across the landscape and provided valuable information about different environmental and anthropogenic factors underlying this compositional differentiation.

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