Pak. J. Agri. Sci., Vol. 43(3-4), 2006

SPATIAL AND SEASONAL VARIATION IN THE SPECIES COMPOSITION OF HERBACEOUS VEGETATION INDIGENOUS TO SOONE VALLEY IN THE SALT RANGE OF PAKISTAN

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The study was conducted to examine the Spatial and seasonal variation in the species composition of herbaceous vegetation indigenous to Soone valley in the Salt range of Pakistan as a baseline for further monitoring and management. Statistical analysis of the data collected from five ecologically diverse sites during two consecutive seasons during 2003 showed significant differences among sites and seasons in the species composition (biomass, stem density and species richness). The ordination of the data showed almost all the grasses confined to summer season and forbs predominantly occurring during winter season at more fertile sites.

INTRODUCTION

An understanding of the factors generating spatial and temporal patterns in the species composition of plant communities plays a pivotal role for developing a suitable strategy for their management and conservation. Previous studies on a wide variety of plant communities have also shown much variation along spatial and temporal scales (Wiens 1989, Schneider 1994, Ysebaert and Herman 2002). The importance of physical characteristics of the environment, particularly the heterogeneity in soil properties, topographic variation, and the growth patterns of plants in determining the spatial variation in plant communities is well documented (Dale et al. 1992, Hyvonen et al. 2005). With the development of ordination models (Borcard et al. 1992, Okland and Eilertsen 1994, Birks 1996) the description of species environment relationship with respect to environmental and spatial gradients has become very common. However, a little attention has been paid to systematically analyze the endangered plant communities in Pakistan.

Anthropogenic disturbances have markedly reduced the size of natural plant communities in Pakistan. The remaining plant communities are also losing their species richness at an alarming rate due to clear cutting, extensive exploitation of grasslands for raising cattle, introduction of exotic plant species and deteriorating environmental conditions. These circumstances necessitate the development of appropriate strategies for the conservation of remaining highly endangered and undocumented unique plant communities like those indigenous to Soone valley in the Salt range of Pakistan.

Soone Valley located between 32.11° and 32.55° N latitude and 72.71° and 72.19° E longitude, is regarded the heart of Salt Range, a 175 km thrust between Himalayan Mountains and Indus plains in Pakistan. Falling within the precincts of subtropical region its elevation ranges from 250 to 1,520 m, with its highest peak being 1,524 m at Skaser (Chaudhary 1969). Its climate varies widely with four pronounced seasons. Temperatures fall below freezing during winter and remain mild during summer as compared to fellow plains. The summer monsoons during July and August cause most of torrential rainfall that remains very scarce in the remaining part of the year (Anonymous 2005). Besides its undulating lands, brine lakes i. e. Khabeki and Ucchali (RAMSOR wetland habitats since 1974) impart it special ecology in the region. Due to vast heterogeneity in the macro and microenvironments, the indigenous plant diversity predominantly open scrub type throughout the region (Roberts 1991) reveals large spatial and temporal variation. Currently this unique vegetation is highly threatened due to hostile environmental conditions, especially the aridity and anthropogenic disturbances.

This study was designed under an Agricultural Linkage Program (ALP) project sponsored by Pakistan Agricultural Research Council to explore the spatial and seasonal variation in the herbaceous plant communities indigenous to Soone valley in Pakistan as a prerequisite for developing a conservation plan.

MATERIALS AND METHODS

Site selection

This sampling program was set up for the first time as a baseline study for the investigation of changes resulting from human impact and environmental variation. We arbitrarily selected five representative sites namely Khabeki Site, Anga Site, Sodhi Site, Ucchali Site and Knotty Garden Site, on the basis of variation in their ecological attributes, especially topography, physiognomy and soil composition as briefly described:

i). Anga Site: It is located at 32°.35' N 72°.05' E at an altitude of 769 m about 20 Km away from Noshehra, the major town in the Soone valley. It is highly diverse site from wildlife point of view but severely degraded site in respect of plant diversity.

ii). Knotty Garden site: Knotty garden is located at 32°.40' N and 72°.14' E at 783 m elevation from sea level. Its distance from Noshehra is 25 Km. It was established during the British Regime in the subcontinent India for propagating the late citrus variety, Valencia and other fruit plants. Presently it has been extremely degraded especially due to shortage of rainfall in the valley.

iii). Sodhi Site: This site was selected near a wildlife sanctuary. Its soil comprises mostly limestone. It is located about 15 Km away from Noshehra at an altitude of 770 m from the sea level being located at 32°.34' N and 72°.13' E. It comprises many natural spring rich in plant diversity.

iv). Ucchali Site: This site was specified along a creek (Nullah) regarded as watershed. Its soil comprises both limestone and sandstone rocks. Natural springs can also be examined at this site. At 32°.32' N and 72°.02' E its altitude is 686 m and it is about 20 Km away from Noshehra.

v). Khabeki Site: It is located at 32°.35' N and 72°.12' E at an elevation of 774 m being 8 Km away from Noshehra. In 1976 the Government of Pakistan declared it as a Wetland Ramsor Site comprising an area of 1700 acres.

For each site we collected data from forty randomly selected quadrates measuring 1 m^2 from a 100 m^2 transect once during the summer season (July 1-10, 2002) and second time in winter season (January 5-15, 2002). The number of individuals of each species was counted and aboveground plant organs were clipped for subsequent determining of dry biomass for each species.

STATISTICAL ANALYSIS

To assess the spatial and temporal effects on the herbaceous vegetation indigenous to Soone Valley first we subjected the data to SPSS. It enabled us to determine the differences among sites and between seasons. To assess the overall variation patterns in species biomass due to three explanatory variables (sites, seasons fertility) we subjected the data to Detrended Correspondence Analysis (DCA) using CANOCO 4.5 package (ter Braak and Smilauer 2002). The axis corresponding to main gradients are unconstrained by explanatory variables, but passively projected on an ordination scatter plot. We performed a series of separate canonical correspondence analysis (CCA) and Partial Constrained Correspondence Analysis (pCCA) tests as well, to work out the gross and net effects of explanatory variables on species composition. For gross effects we used a single explanatory variable, always followed by 999 permutation tests for the first canonical analysis. To determine the particular effects (net effects) due to a specific variable we performed pCCA that partitioned out the effects shared with other variables used as co-variables. The proportion of variation explained by each environmental variable was worked out from the ratio of particular canonical eigenvalues to the sum of all eigenvalues (total inertia) (Borcard et al. 1992).

RESULTS

Species biomass, stem density and richness showed highly significant variation among sites, between seasons and for the interaction between sites and seasons. A comparison among the sites indicates maximum biomass for Ucchali site during the summer season followed by Khabeki site varying non-significantly (Fig. 1). The minimum biomass during summer season was recorded for Knotty Garden site. The biomass levels of plant species at Anga site comprised the intermediate position. The biomass levels of plant communities at different sites displayed almost the same pattern as that recorded during summer season. Moreover, with the exception of Anga site, at all other sites biomass levels recorded during winter season did not vary significantly from those observed during summer season.

In terms of stem density recorded during summer season, the study sites can be conveniently divided in to three categories. The first category is comprised of Ucchali and Khabeki sites, where stem density was recorded significantly higher than that examined at Anga and Knotty garden sites. The second category includes Anga and Knotty Garden sites which had the lowest stem density and did not differ significantly with each other. The third category includes Sodhi sites which comprised intermediate stem density and did not differ significantly from both the maximum and minimum bounds. A similar pattern was recorded for stem density during the winter season.

Species richness exhibited almost the same pattern as that recorded for biomass and stem density. During summer season only Ucchali site varied significantly from Anga and Knotty garden sites having the lowest species richness. Among other sites the differences in their species richness were not significant. Moreover, during the winter season, only Anga site had significantly higher species richness than that recorded during summer season. All other sites showed non-significant variation in their species richness during both seasons.

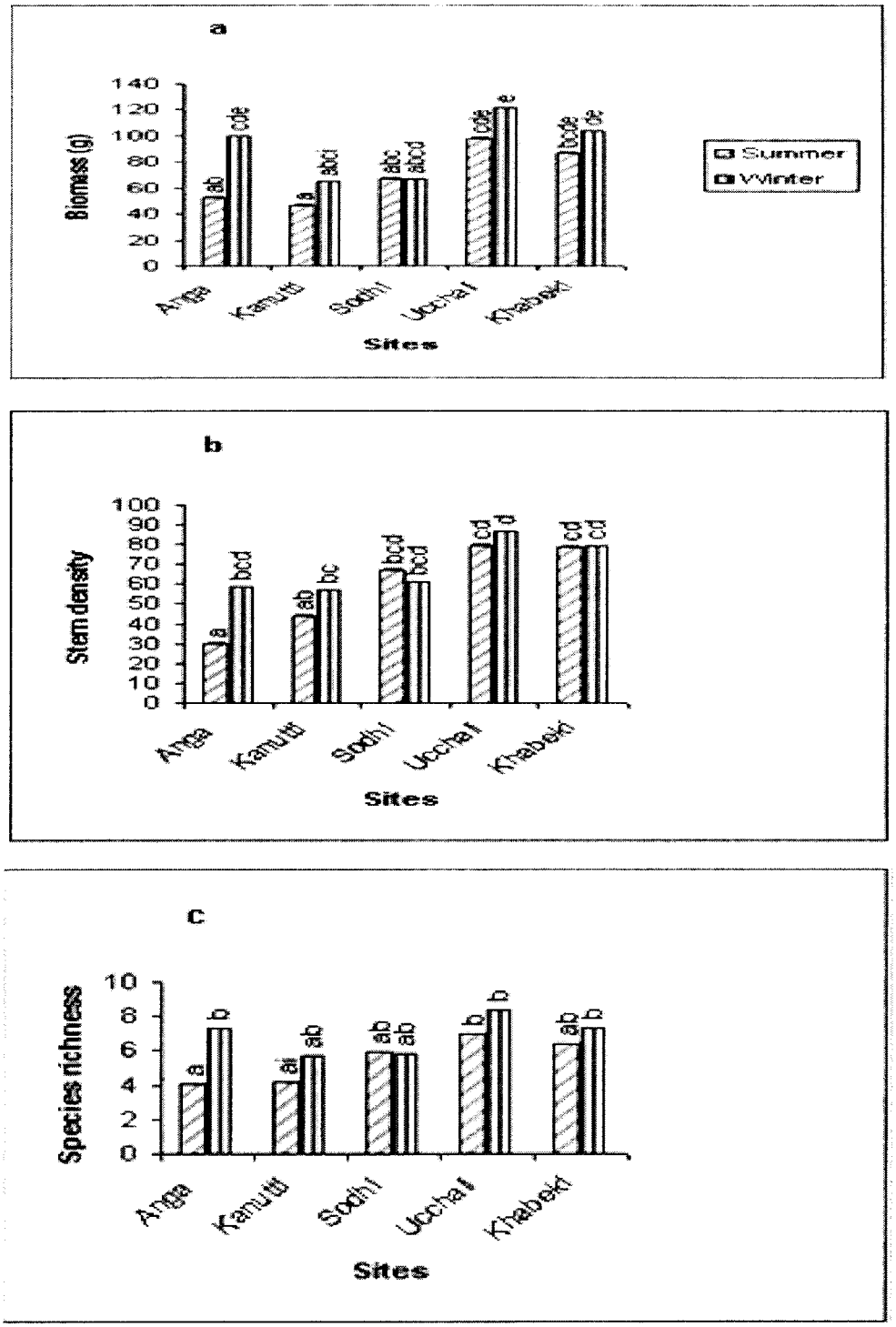

Fig. 1. Mean values for a) biomass, b) stem density, c) species richness of plant communities at different sites in Soon Valley during winter and summer seasons.

A join biplot of species biomass and all the environmental variables revealed seasonal gradient along Axis 1, displaying winter season towards right side and summer season on the opposite direction towards left side (Fig. 2). The second gradient along season. Among the forbs Astragalus, *Medicago denticulata* and *Solanum nigrum* showed almost equal distribution during both seasons. Suaeda a high salt tolerant species was also abundantly occurred during the summer season. The distribution of pant species

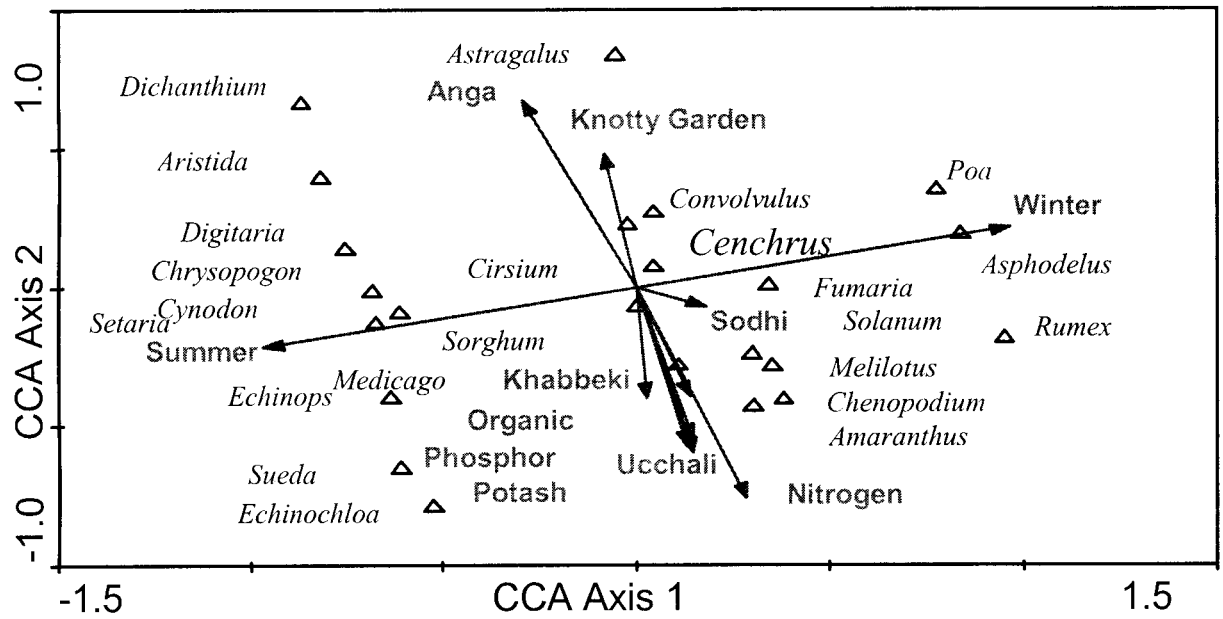

Fig. 2. Detrended Correspondence analysis (DCA) of species biomass passively projecting the explanatory variables. Species names indicated by the first four letters of generic names as follows: *Aristida = Aristida royleana, Asphodelus = Asphodelus tenuifolius, Astragalus = Astragalus punjabicus, Amarantus = Amarantus viridis, Cenchrus = Cenchrus pennisetiformis, Chenopodium = Chenopodium album, Convolvulus = Convolvulus arvensis, Cirsium = Cirsium arvensis, Chrysopogon = Chrysopogon sp, Cynodon = Cynodon dactylon, Dichanthium = Dichanthium annulatum, Digitaria = Digitaria marginata, Echinops = Echinops echinatus, Echinochloa = Echinochloa colonum, Fumaria = Fumaria indica, Medicago = Medicago denticulata, Melilotus = Melilotus indica, Poa = Poa annua, Rumex = Rumex dentatus, Solanum = Solanum nigrum, Setaria = Setaria glauca, Sorghum = Sorghum halepense, Sueda = Sueda fruticosa.*

Axis 2 corresponds to spatial gradient. Anga and Knotty garden sites located at high altitude are displayed at the top of Axis 2 while Ucchali and Khabbeki sites having low altitude occupy the bottom position along Axis 2. Nevertheless Sodhi site with intermediate altitudinal levels is represented in the near the centre along Axis 3. The third axis corresponds to soil fertility gradient indicating all the soil nutrients (nitrogen, phosphorus, potash, organic matter) positively related to low altitude (Ucchali and Khabbeki sites), and negatively related to high altitude (Anga and Knotty garden sites). Sodhi site being in the center occupy intermediate position in respect of soil fertility.

The seasonal distribution of species showed a clear-cut variation between the summer season grasses and winter season forbs. With the exception of *Poa annua*, *Cenchrus pennisetiformis* and *Sorghum halepense*, all other grasses commonly occurred during the summer showed clear-cut spatial differences as well. *Sueda fruticosa* a salt tolerant species, more commonly occurred at Khabeki site, *Aristida royleana*, *Astragalus punjabicus* and *Dichanthium annulatum* at Anga site. Both leguminous species i. e. *Melilotus indica* and *Medicago denticulata* predominantly occurred at Ucchali site.

The partitioning of species biomass data explained highly significant gross and net effects relating to sites, seasons, the interaction between sites and seasons, and due to combined effect of all explanatory variables (Table 1). Net effects of soil fertility were also highly significant but their gross effects were marginally significant. The maximum net effects were associated with the interaction between sites and seasons followed by the net effects due to all explanatory variables. Sites and seasons showed almost same net variation in biomass while the gross seasonal effects

Table 1. Gross and net variation (%) in species biomass and stem density due to seasonal and temporal and their interactive effects calculated through pCCA. Gross effects include the variation explained by particular variable shared with covariables. Net effects correspond to variation explained by specific variable not shared with covariables. * = $p< 0.05$, **= $p<0.01$

Biomass	Gross	F value	Net	F value
Sites	5.42	7.53**	11.71	20.3**
seasons	11.50	59.18**	11.88	53.65**
Fertility	1.08	1.94*	7.20	21.96**
Seasons ∩ Sites	-	-	28.72	18.67**
All explanatory variables	-	-	24.29	10.43**
Stem density				
Sites	20.68	7.79**	10.24	17.72**
Seasons	31.50	63.62**	12.95	59.21**
Fertility	1.09	1.8*	6.24	19**
Seasons ∩ Sites	-	-	27.47	26.78**
All explanatory variables	-	-	23.02	53.65**

were 50% higher than spatial effects. A similar pattern was recorded for the gross and net variation pertaining to stem density.

DISCUSSION

We observed significant spatial and seasonal variation in species composition of plant communities indigenous to soone valley. Partitioning of the data through CCA and pCCA also revealed more seasonal variation than spatial one in both species biomass as well as stem density. A joint biplot of species data and environmental variables indicated that the most important gradients in species composition of Soone Valley vegetation co-varied with altitude and associated climatic factors. The nutritional status of soils was also associated with altitude. We examined a clear distinction between cool season and warm season communities that demonstrates the critical role of environmental variables in shaping the vegetation under study. Unfortunately, no previous studies are available focusing on the effect of spatial and temporal factors on the species composition of plant communities indigenous to Soone valley. However, studies relating to a variety of plant communities in some other geographical areas of the world have reported resembling results (Pyšek 1993, Ysebaert and Herman 2002).

We noted that species richness decreased with altitude which is in accordance with a commonly examined trend (Begon et al. 1996, Pyšek et al. 2002). Lososová et al. (2004) attributed the increase in species richness of weed communities to less intense agriculture because at agricultural lands the use of herbicides undermines the emigration rate of weedy species. In contrast we attribute the low species richness at high altitudes to the lack of agriculture resulting in reduced immigration of seeds of annual weeds as that examined in our study sites at relatively low altitudes in the vicinity of some agricultural fields.

We noted the second most important gradient in species composition related to seasonal dynamics as previously examined (Mihulka 1998). Grasses mostly appeared during summer while short-lived annuals forbs mostly appeared during winter. Lossosova (2004) also examined a similar seasonal trend for weed communities in Finland.

Variation partitioning by CCA proved to be a useful method for detecting the spatial and seasonal variation in species composition and the importance of these explanatory variables. In this study spatial variability was studies in more detail as temporal variability, considering only seasonal variation as temporal component because at this stage we lacked fine scale multi year data.

We have addressed the seasonal and temporal variation in the plant communities indigenous to Soone valley in the Salt range of Pakistan using multivariate analytical suite for the first time. This information will prove a baseline for further monitoring and management of plant communities in Soone valley, Pakistan and resembling vegetation types elsewhere in the world.

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