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# EDAPHIC FACTORS AS MAJOR DETERMINANTS OF PLANT DISTRIBUTION OF TEMPERATE HIMALAYAN GRASSES

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### Abstract

The quantification of the comparative effect of environmental factors on species distribution can improve our knowledge of the processes that drive diversity patterns. Fifteen different habitats in Neelum valley (Kashmir), using quadrat method along altitudinal gradient were studied for the plant ecological attributes including; soil plant interaction, species composition and vegetation cover to test the hypothesis that soil factors are the major determinants of species distribution. Redundancy analysis (RDA) showed a clear impact of soil characteristics on vegetation. *Rostraria pumila*, *Pennisetum orientale*, *Sorghum nitidum* and *Arundinella* sp. had a strong association with the Kail (KL) site influenced by soil Ec. Distribution of *Lolium temulentum*, *Poa nemoralis*, and *Saccharum spontaneum*, at Chilhana (CH) site seemed to be affected by the moisture content only. Species distribution at Nagdar (NG), Kundal shahi (KS), Kairan (KR) and Dawarian (DW) site was affected by $Ca^{2+}$ and $PO_4^{3-}$ content respectively. Diversity pattern at Sharda, Dawarian (DW), and Lawat (LW) sites were driven by $K^+$ and $N^+$ content. Each grass showed a very specific relationship to environmental variables, which imitates the habitat status, ecological adaptation and degree of tolerance in species.

**Key words:** Edaphology, Redundancy analysis (RDA), Environmental variable, Species cover, Himalayan grasses.

## Introduction

Understanding the drivers and mechanisms of changes in species distribution provides basis for making scientifically sound ecological predictions (Hegazy *et al*., 2008). Of the numerous factors affecting species, soil has large impact on the composition and structure of plant community. Heterogeneity of soil properties, such as soil texture, moisture content, electric conductivity (Ec) and pH create niches with specific conditions, which in turn affect distribution pattern of plants (Vazquez & Givnish, 1998).

Poaceae is a species-rich family that includes many economic plants, globally with about 10,000 species and 700 genera (Crisp *et al*., 2009; Linder & Rudall, 2005). Recent phylogenetic studies confirmed that multiple factors are involved indirectly that determine the grass diversity at large scales; Edwards & Smith 2010).

To point out the strength of environmental factors, responsible for the species distribution among ecosystems is a big task for ecologists (Hegazy *et al*., 2008). Species diversity mainly depends on the occurrence, abundance and vegetation cover. Grasslands, in which grasses are the most important floristic component, cover about 40% of the earth surface (Peterson *et al*., 2010).

Plant distribution is controlled on large by climate and over small scale by environmental heterogeneity (Lavers & Field, 2006). Climate affects the input of the resources needed for the plant growth, such as moisture, radiations and temperature while environmental heterogeneity (topography, aspect) determines the number of realized environmental gradient combinations in a particular landscape (Huston & De Angelis, 1994). The greater number of the combinations, the greater number of niches will available for plant growth, enable more plant species to co-exist (Tilman, 1982; Smith & Huston, 1989).

There is a significant relationship between species diversity, distribution and moisture availability (Leathwick *et al*., 1998). Vegetation structure in savanna and grassland regions is mainly determined by moisture content (Scholes *et al*., 1997) and precipitation is considered to be important factor affecting the plant distribution (Cody, 1989). Soil pH directly affects the nutrients availability, nutrient toxicity, and microbial activity, as well as extending the direct effect on protoplasm of the root cells (Gould & Walker, 1999).

Himalayan ecosystems all over the world usually have very specific diverse biological communities. Although large number of review and reports are available in Indian and Nepal Himalayas but less attention has been given the western Himalaya of Pakistan due to remoteness of the area (Tanner *et al*., 1998). Keeping in mind the need and importance of ecological indicators for the conservation and management of wild plant resource, the present work was designed to explore the relationship between soil factors and species cover over a large distributional area.

## Materials and Methods

**Study area:** The Neelum Valley (Kashmir) a temperate Himalayan region, situated at an altitude of 900-6,325 m above sea level (a.s.l.), lies between 73-75° E longitude and 32-35° N latitude. The climate is characterized by cold winter (average 1-4ºC) and moderate summer (average temperature (22-30ºC). The average rainfall is 165 cm annually. Soil is loamy and sandy loam, adept to hold moisture and suitable for the growth of forests (Ahmad *et al*., 2012).

**Soil variables and data analysis:** Soil samples were taken from 15 sampling points to analyze the 9 soil variables for physicochemical characteristics. The area location and altitude were determined with the help of Global Positioning System (GPS) and the slope gradient and slope aspects were measured using a compass. Soil moisture was calculated by way of drying, and pH and electrical conductivity by using a pH/Ec meter (WTW series InoLab pH/Cond 720). Soil organic matter was determined by $K_2Cr_2O_7$-$H_2SO_4$ oxidation method of Walkley-Black, total nitrogen content was determined by diffuse method, available P was determined by Bray-P method.The flame photometric method was used to estimate $K^+$ and $Ca^{2+}$ cations. $Cl^-$ content was measured with the help of chloride meter (Jenway, PCLM).

**Vegetation sampling:** The vegetation was sampled by quadrat method and 1 $m^2$ quadrat were used at five sampling points along a straight transect line, and each sampling point was selected 20 m away from subsequent quadrat. At each sampling point 25 quadrat were laid perpendicular to a straight transect line for the vegetation study to record the data for percent cover of each species in each quadrat.

**Statistical analysis:** Analysis of variance for soil variables and ecological parameters was determined (Steel *et al*., 1997) and the means were compared by applying the LSD test. The Redundancy Analysis (RDA) technique used to evaluate the impact of different ecological variables on species distribution using Canoco Computer Package for Windows [Version 4.5].

## Results

**Soil physiochemical characteristics:** Most of the soil characteristic varied significantly at $p<0.005$ except soil organic matter and $Ca^{2+}$ showed non-significant difference among the all study sites. The soil moisture content seemed to be closely related to the physical properties of the soil as well as to vegetation type. The main factor affecting soil moisture was precipitation. The pH of the soil varies from 4.6 to 8.2 mostly acidic and tends to be slightly basic with low content of exchangeable cations at Chilhana (CH) and Jura (JR) sites. A significant difference was also observed in Ec, saturation percentage and ionic contents of the soil in the analysis (Table 1).

**Taxonomic diversity and percentage cover:** A total of 52 species of grasses belonging to 10 tribes and 28 genera were recorded from 15 sampling sites in Neelum Valley. Poaeae was the largest tribe (12 spp.); followed by Andropogoneae (11 spp.); Aveneae (9 spp.); Paniceae (8 spp.); Aristideae and Brachypodieae (3 spp. each), whereas, rest of the 5 tribes represents 2 or 1 species. Dodonial was species rich site with 15 species (28.85%), followed by Dawarian, Sharda, and Taobut (12 spp.), Kairan, Nagdar and Halmat with 11 species (Table 2).

*Agrostis pilosa* and *Agrostis viridis* showed high percent cover at Athmuqam and Kundal Shahi respectively. *Apluda mutica* showed high cover at Dawarian and Halmat. *Aristida cynantha* occupied high cover area at Jura and Dodonial. *Aristida funiculata* showed high frequency at Kundal shahi but it was present at Halmat with low frequency. *Aristida mutabilis* showed high cover at Athmuqam. *Arthraxon prionodes* showed high cover area at Kail. *Arundinella nepalensis* and *Arundinella* sp., showed its maximum cover area at Nagdar and Kail sites respectively. *Avena byzantina* and *Avena fatua* showed their maximum cover Athmuqam and Janwai and Tao butt respectively. *Bothriochloa bladhii* showed the maximum cover at Janawai and *Bothriochloa pertusa* was present at Nagdar and Tao butt. Both *Brachypodium distachyon*, and *Brachypodium* sp., showed their consistent presence at four study sites where Brachypodium sp., showed relatively low cover at Dodonial. *Brachypodium sylvaticum* and *Capillipedium parviflorum* showed their maximum cover at Kundal Shahi and Chilhana sites. *Cenchrus pennesitformis* showed low cover values at Dodonial. *Cynodon dactylon* grass showed its maximum maximum cover at Dodonial, with moderate cover at Sharda. *Digitaria cruciata* was the only grass that showed high cover at Kundal Shahi, Nagdar and Sharda (SH). *Eleusine indica* was present at Kairan with high cover. *Festuca Kashmiriana* showed high cover at Sardari and *F. levengei* was present at Sharda with moderate cover. *Festuca simlensis* showed its maximum cover at Sharda. *Heteropogon contortus* showed maximum cover at Dodonial. *Hordeum glacum* showed moderat cover value at Kairan and *Hordeum marinum* was present at Chilahana with high cover. *Koeleria cristata* showed low cover area at Kairan and *K. macrantha* showed showed high cover at Nagdar. *Lolium perenne* showed its maximum cover at Tao butt whereas, *temulentum* was the only grass that showed its maximum cover at Kail and Halmat. *Milium effusum* was present at Nagdar with moderate cover. *Panicum atrosanguineum* was present at Jura and Sardari with moderate cover. *Panicum decompositum* showed its moderate cover at Dodonial, Halmat and Taobutt. *Parapholis incurva* was moderately present at Jura. *Pennesitum orientale* was with high cover at Sardari. *Poa argunensis*, *Poa attenuata* and *Poa falconeri* showed theri maximum cover at Sharda, Sardari and Lawat respectively. *Poa infirma* and *P. nemoralis* was present with moderate and high cover at Kairan and Chilhana respectively. *Polypogon monspeliensis* was present with high cover at Athmuqam. *Rostraria clarkeana* showed high cover at Jura and low at Sharda. *Rostraria pumila* showed high cover at Kail and relatively low cover at Jura, Athmuqam and Dawaraian. *Saccharum filifolium* showed its maximum cover at Kairan whereas *Sacchrum spontaneum* was with high cover at Chilhana. *Schizachyrium impressum* showed moderate cover at Athmuqam with relative low cover at Athmuqam, Lawat and Dawarian. *Setaria pumila* showed low cover at Kundal Shahi. *Sorghum arundinaceum* showed high cover at Janawai and low cover at Dodonial. *Sorghum nitidum* was present at Kail (Kl) with relatively very high cover area (Table 3).

**Table 1. Soil physico-chemical characteristics of study sites of Neelum Valley, Azad Jammu and Kashmir.**

| | CH | JR | KS | AT | KR | NG | LW | DW | DD | SH | KL | JW | SR | HL | TB | F ratio | LSD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil pH | $8.2^{a}$ | $6.9^{ab}$ | $5.8^{bcdef}$ | $4.6^{bcdef}$ | $5.7^{bcdef}$ | $6.2^{abcd}$ | $4.9^{def}$ | $5.4^{cdef}$ | $5.7^{ef}$ | $7.0^{abcde}$ | $6.3^{cdef}$ | $5.6^{f}$ | $7.2^{abcd}$ | $7.9^{abcdef}$ | $7.4^{abc}$ | 2.71** | 1.3146 |
| S (%) | $46.64^{b}$ | $26.93^{i}$ | $38.76^{fg}$ | $46.32^{bc}$ | $30.64^{h}$ | $43.49^{cd}$ | $30.85^{h}$ | $40.38^{ef}$ | $30.52^{h}$ | $52.34^{a}$ | $40.06^{de}$ | $37.15^{g}$ | $47.87^{b}$ | $47.06^{bc}$ | $45.05^{bcd}$ | 58.9** | 2.8850 |
| ECe (dS $m^{-1}$) | $8.8^{a}$ | $8.7^{a}$ | $6.6^{efg}$ | $5.8^{gh}$ | $6.8^{def}$ | $8.0^{abc}$ | $6.8_{def}$ | $7.6^{bcd}$ | $8.4a^{b}$ | 8.6a | $5.7^{h}$ | $7.4^{cde}$ | $7.7^{bc}$ | $6.4^{fgh}$ | $6.8^{def}$ | 13** | 0.8241 |
| $K^{+}$ mg $L^{-1}$ | $8.47^{d}$ | $8.97^{cd}$ | $9.93^{bc}$ | $9.43^{bcd}$ | $9.04^{cd}$ | $8.66^{d}$ | $9.^{1bcd}$ | $8.45^{d}$ | $8.67^{d}$ | $10.02^{b}$ | $8.58^{d}$ | $8.98^{cd}$ | $11.22^{a}$ | $9.44^{bcd}$ | $8.89^{d}$ | 4.6* | 0.9704 |
| $Ca^{2+}$ $L^{-1}$ | $4.18a^{b}$ | $3.7^{b}$ | $4.58^{ab}$ | 3.67a | $4.34^{ab}$ | $3.78^{b}$ | $4.52^{ab}$ | $4.86a^{b}$ | $4.22^{ab}$ | $4.46^{ab}$ | $3.97^{ab}$ | $4.42^{b}$ | $4.82^{ab}$ | $3.67^{b}$ | $3.55^{ab}$ | 0.72ns | 1.8851 |
| $PO_4^{3-}$ (mg $L^{-1}$) | $92.14^{a}$ | $83.52^{f}$ | $92.01^{a}$ | $88.66^{c}$ | $80.93^{gh}$ | $81.22^{g}$ | $77.45^{j}$ | $71.08^{k}$ | $80.06^{h}$ | $87.67^{d}$ | $84.02^{f}$ | $86.04^{e}$ | $78.06^{j}$ | $90.56^{b}$ | $79.07^{i}$ | 356** | 0.9254 |
| $Cl^{-}$ (mg $L^{-1}$) | $0.6de^{f}$ | $0.8^{cdef}$ | $0.4^{ef}$ | $1.1b^{cde}$ | $1.3^{bcd}$ | $1.8^{ab}$ | $0.9^{cdef}$ | $1^{cdef}$ | $1.2^{bcd}$ | $2.0^{a}$ | $1.5^{abc}$ | $0.8^{cdef}$ | $0.3^{f}$ | $0.4^{ef}$ | $0.7^{def}$ | 4.08* | 0.7209 |
| TN (%) | $0.118^{b}$ | $0.105^{b}$ | $5.55^{a}$ | $0.111^{b}$ | $0.109^{b}$ | $0.099^{b}$ | $0.107^{b}$ | $0.121^{b}$ | $0.10^{b}$ | $0.104^{b}$ | $0.116^{b}$ | $0.096^{b}$ | $0.112^{b}$ | $0.103^{b}$ | $0.122^{b}$ | 1007** | 0.1293 |
| OM (%) | $2.38^{a}$ | $2.09^{a}$ | $2.03^{a}$ | $2.36^{a}$ | $2.22^{a}$ | $2.06^{a}$ | $2.04^{a}$ | $1.84^{a}$ | $2.13^{a}$ | $2.42^{a}$ | $1.92^{a}$ | $1.98^{a}$ | $1.88^{a}$ | $2.27^{a}$ | $1.98^{a}$ | 0.34ns | 0.9563 |
| Soil texture | SCL | SCL | SL | SL | L | CL | SL | CL | L | SL | L | CL | L | CL | CL | | |

S (%) = saturation percentage, ECe = Electric conductivity, TN = Total nitrogen, OM = Organic matter, SCL = sandy clayey loam, SL = sandy loam, L = loam, CL = clayey loam

Study sites: Chiliahana (CH), Jura (JR), Kundal Shahi (KS), Athmuqam (AT), Kairan (KR), Lawat (LW), Dawarian (DW), Dodonial (DD), Sharda (SH), Kail (KL), Janawai (JW), Sardari (SD), Halmat (HM), Tao but (TB).

Mean within rows sharing same letter are non-significant at $p<0.05$ level ($n= 3$)

*,** = significant at 0.05 and 0.001 levels, respectively. Ns = non-significant

**Table 2. Meteorological and topographical data of sampling sites in Neelum Valley Azad Jammu & Kashmir.**

| Sampling sites | Coordinates | Altitude (m) | Slope (%) | Aspect | Observed taxa | %age |
|---|---|---|---|---|---|---|
| Chiliahana | 34º 23’ 56.1” N<br>73º 46’ 29.5” E | 1100 | 60-70 | Eastern | 9 | 17.31 |
| Jura | 34º 29’ 26.9” N<br>73º 50’ 04.8” E | 1290 | 55-65 | Western | 11 | 21.15 |
| Kundal Shahi | 34º 33’ 03.6” N<br>73º 50’ 52.2” E | 1318 | 40-50 | North-eastern | 8 | 15.38 |
| Athmuqam | 34º 35’ 33.9” N<br>73º 55’ 0.72” E | 1403 | 20-35 | Western | 13 | 25.00 |
| Kairan | 34º 38’ 54.3” N<br>73º 56’ 57.1” E | 1499 | 20-25 | Northern | 11 | 21.15 |
| Nagdar | 34º 40’ 24.7” N<br>73º 57’ 20.0” E | 1555 | 50-60 | North-western | 11 | 21.15 |
| Lawat | 34º 41’ 15.9” N<br>73º 58’ 11.3” E | 1579 | 40-50 | Southern | 11 | 21.15 |
| Dawarian | 34º 43’ 25.1” N<br>74º 59’ 58.1” E | 1807 | 35-45 | Northern | 12 | 23.08 |
| Dodonial | 34º 41’ 58.78” N<br>74º 06’ 03.09” E | 2774 | 20-30 | Southern | 15 | 28.85 |
| Sharda | 34º 47’ 03.9” N<br>74º 10’ 47.6” E | 2014 | 25-35 | East-western | 12 | 23.08 |
| Kail | 34º 48’ 58.2” N<br>74º 25’ 09.7” E | 2047 | 15-25 | North-western | 9 | 17.31 |
| Janawai | 34º 47’ 23.0” N<br>74º 33’ 56.0” E | 2187 | 30-40 | Western | 8 | 15.38 |
| Sardari | 34º 45’ 44.1” N<br>74º 38’ 17.3” E | 2239 | 15-20 | South-eastern | 10 | 19.23 |
| Halmat | 34º 46’ 42.6” N<br>74º 40’ 28.9” E | 2267 | 5-15 | Eastern | 11 | 21.15 |
| Tao butt | 34º 43’ 42.7” N<br>74º 43’ 26.3” E | 2300 | 5-10 | East-western | 12 | 23.08 |

**RDA analysis:** RDA ordination biplot (Fig. 1) indicated a strong effect of soil characteristics on distribution of grasses at different habitats. *Rostraria pumila*, *Pennisetum orientale*, *Sorghum nitidum*, and *Arundinella* sp. showed a strong association with the KL site with strong influence of soil Ec. Distribution of *Lolium temulentum*, *Poa nemoralis*, and *Saccharum spontaneum*, at CH site was seemed to be affected by the moisture contents. Distribution of *Heteropogon contortus*, *Parapholis incurva*, *Setaria pumila*, *Agrostis viridis*, *Capillipedium parviflorum*, *Panicum humile; Koeleria cristata*, *Bothriochloa pertusa*, *Digitaria cruciata*, *Aristida funiculate*, *Hordeum glaucum*, and *Eleusine indica* species, strongly associated to the NG, KS, KR sites, were affected by $Ca^{2+}$ content. *Bothriochloa bladhii* at PW site was controlled by $PO_4^{3-}$ content. Presence of *Festuca kashmiriana*, *Poa argunensis*, *Poa falconeri*, *Sorghum arundinaceum* species at SH, DD, LW sites seemed to be influenced by $K^+$ and $N^+$ content. *Aristida cyana, Aristida mutabilis*, *Cenchrus* sp., *Poa attenuata*, were more associated with SR whereas, *Panicum atrosanguineum* with JR, and *Agrostis pilosula* and *Avena byzantine* were associated with AT site. Distribution of *Aristida funiculata*, *Koeleria macrantha* species at TB site was not influenced by any of the soil factor.

## Discussion

Mechanism for species turnover is still poorly understood due to dispersal limitation and environmental variables that are considered to shape the distribution of species (Davidar *et al*., 2007). Soil nutrients which are related to moisture can play a major role in species distribution (Phillipse, 2003). Among all, clay soils with greater amount of nutrients and water availability have higher support for thick vegetation cover (Schuur & Matson, 2001).

A strong association can be observed in grasses such as, *Rostraria pumila*, *Pennisetum orientale*, *Sorghum nitidum*, and *Arundinella* sp. with the KL site. The distributional pattern of these species seemed to be strongly influenced by soil Ec. Occurrence of *Lolium temulentum*, *Poa nemoralis*, and *Saccharum spontaneum*, at CH site was likely to be affected by the moisture contents. Moisture contents of the soil depends upon the composition of the soil, availability of nutrients and topography of the area (Michael *et al*., 2002).

*Agrostis viridis*, *Capillipedium parviflorum*, *Panicum humile*, *Koeleria cristata*, *Bothriochloa pertusa*, *Digitaria cruciata*, *Aristida funiculata*, *Hordeum glaucum*, *Eleusine indica*, strongly associated to the NG, KS, KR sites, were together affected by $Ca^{2+}$ content. *Bothriochloa bladhii* strongly associated with PW rather than DW was affected by $PO_4^{3-}$ content. Study sites SH, DD, LW were strongly associated with the distribution of *Festuca kashmiriana*, *Poa argunensis*, *Poa falconeri*, *Sorghum arundinaceum* species and $K^+$ and nitrogen of the soil seemed to influence the distribution pattern of the species over these sites. Nitrogen in inorganic and extractable form had little impact on species distributions (Ros *et al*., 2011).

*Aristida cyanatha*, *Aristida mutabilis*, *Cenchrus* sp., *Poa attenuata*, *Panicum atrosanguineum*, *Agrostis pilosula* and *Avena byzantine* were more associated with SR, JR, and AT sites. The distribution of these grasses over these sites was under the influence of soil pH and $Cl^-$ content. Among the soil properties affecting the species distribution, soil pH, electric conductivity (EC) and moisture content may play the most important role (Pausas & Austin, 2001). Species response to pH varies from vegetation structure in savanna and grassland regions is mainly determined by moisture content (Scholes *et al*., 1997) and precipitation is considered to be one factor effecting the plant distribution (Cody, 1989). Soil pH directly affects the nutrients availability, nutrient toxicity, and microbial activity, and extends the protoplasm of the root cells (Marschner, 1986; Gould & Walker, 1999).

TB site is strongly associated with the distribution of the *Aristida funiculata*, and *Koeleria macrantha*. This site was not influenced by any of the soil physico-chemical characteristics. These outcomes indicate the role of other environmental gradients such as temperature and radiation, pattern of rainfall and availability of nutrient which may have a combined effect of plant distribution. Vegetation patterns is controlled by many environmental gradients as a one dimensional environmental gradient is meaningless until defined in the term of other environmental conditions, and generalization about one gradient is conditional upon other variables (Austin & Heyligers, 1989).

Along altitudinal gradient a significant decrease in vegetation cover can be observed. Elevation as an environmental factor has a multifaceted influence on the distribution patterns of plant species (Zhao & Fang, 2006). The pragmatic decrease in species distribution is due to deforestation, human interaction, and quick disappearance of annual plants because of cold conditions (Malik *et al*., 2007). Areas with high altitude are the hotspot for biodiversity with large number of species due to human impact (Nogues *et al*., 2008). Himalayan high altitude plains above the tree line are cold (Nautiyal *et al*., 2004), and dry hyper optimal habitats with varying phytodiversity (Sharma *et al*., 2009; Grytnes & Vetaas, 2002).

*Digitaria cruciata,Cynodon dactylon Arthraxon prionodes*, *Heteropogon contortus*, *Apluda mutica*, *Cenchrus pennisetiformis*, *Festuca simlensis*, and *Saccharum filifolium* are the grasses with broad range of distribution over various sites. DD had the maximum species cover, followed by AT, DW, TB and SH sites. A strong correlation between species cover and environmental factors has been reported (Lavers & Field, 2006). Different species have different need for moisture, soil nutrient content and amount of radiation received. The distribution of the species within any ecosystem is the function of numerous biotic and abiotic factors which makes it difficult to investigate the effect of single environmental factor. Different species respond differentially to environmental factors. The maximum species can be found in the sites with high temperature, intermediate rainfall, low radiation and high nutrient levels (Minchin, 1989; Gould & Walker, 1999).

The findings of the present study revealed that edaphic factors are likely to be of particular importance in investigating the pattern of vegetation dynamic and response of the species toward particular soil variable. These patterns differ considerably are related to different adaptation strategies of the species to soil conditions. Therefore, it can be concluded that soil factors are not only the key drivers for the distribution of species over various habitats. It is likely to be governed by the combined effect of soil structure and composition, soil moisture, available nutrients and other environmental variables over the distribution of individual species.

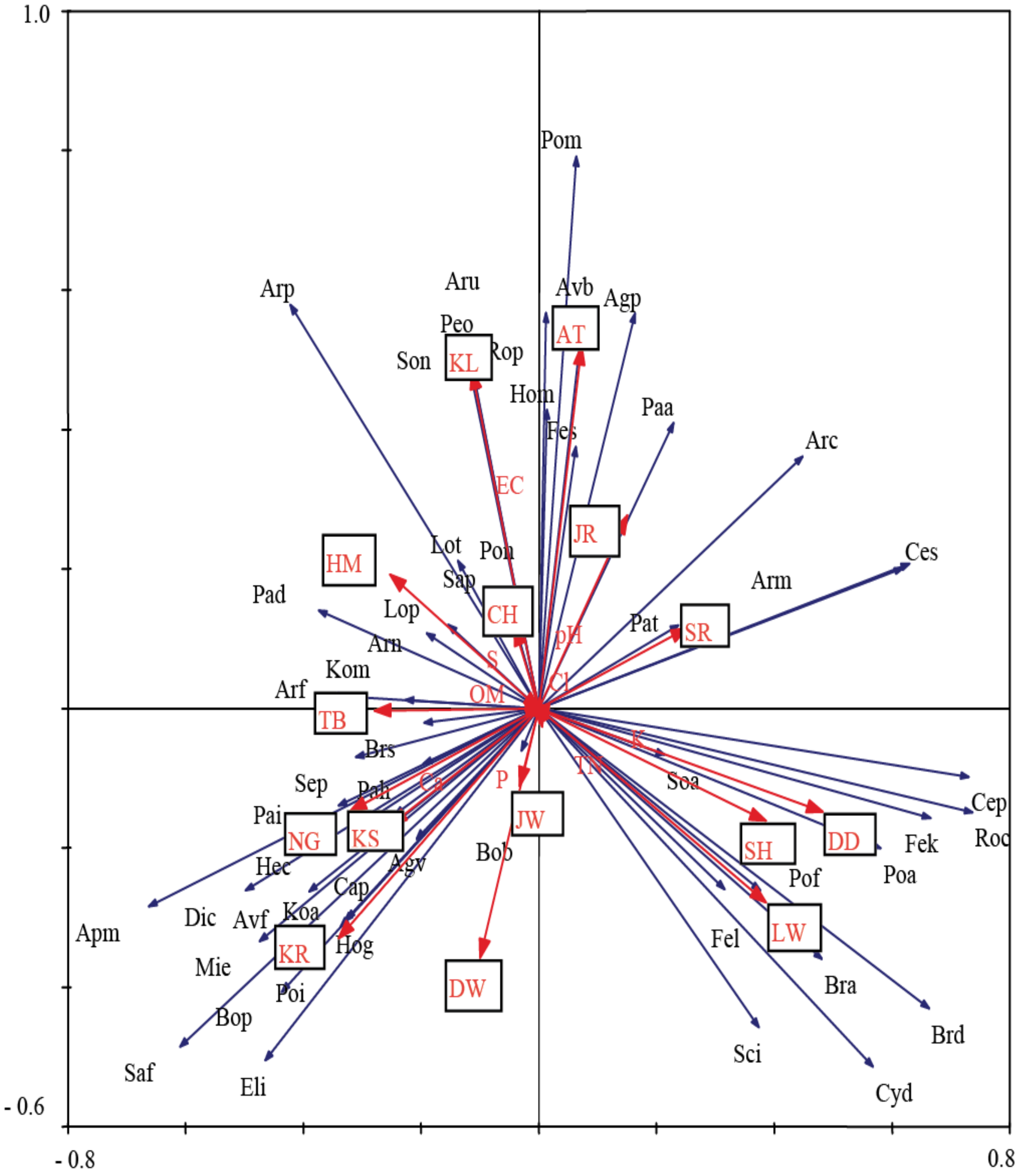

Fig. 1. RDA ordination showing the effect of soil physio-chemical characteristic on distribution of grasses at different cites at Chiliahana (CH), Jura (JR), Kundal Shahi (KS), Athmuqam (AT), Kairan (KR), Lawat (LW), Dawarian (DW), Dodonial (DD), Sharda (SH), Kail (KL), Janawai (JW), Sardari (SD), Halmat (HM), Tao but (TB).

**Key to species:** ***Agp***: *Agrostis pilosula;* ***Agv***: *Agrostis viridis;* ***Apm***: *Apluda mutica;* ***Arc***: *Aristida cyanantha;* ***Arf***: *Aristida funiculate;* ***Arm***: *Aristida mutabilis;* ***Arp***: *Arthraxon prionodes;* ***Arn***: *Arundinella nepalensis;* ***Aru***: *Arundinella* sp; ***Avb***: *Avena byzantine;* ***Avf***: *Avena fatua;* ***Bob***: *Bothriochloa bladhii;* ***Bop***: *Bothriochloa pertusa;* ***Brd***: *Brachypodium distachyon;* ***Bra***: *Brachypodium* sp; ***Brs***: *Brachypodium sylvaticum;* ***Cap***: *Capillipedium parviflorum;* ***Cep*** *Cenchrus pennisetiformis;* ***Ces*** *Cenchrus* sp; ***Cyd***: *Cynodon dactylon;* ***Dic***: *Digitaria cruciata;* ***Eli***: *Eleusine indica;* ***Fek***: *Festuca kashmiriana;* ***Fel***: *Festuca levingei;* ***Fes***: *Festuca simlensis;* ***Hec***: *Heteropogon contortus;* ***Hog***: *Hordeum glaucum;* ***Hom***: *Hordeum marinum;* ***Koa***: *Koeleria cristata;* ***Kom***: *Koeleria macrantha;* ***Lop***: *Lolium perenne;* ***Lot***: *Lolium temulentum;* ***Mie***: *Milium effusum;* ***Paa***: *Panicum atrosanguineum;* ***Pad***: *Panicum decompositum;* ***Pah***: *Panicum humile;* ***Pai***: *Parapholis incurve;* ***Peo***: *Pennisetum orientale;* ***Poi***: *Poa infirma;* ***Poa:*** *Poa argunensis;* ***Pat***: *Poa attenuate;* ***Pof***: *Poa falconeri;* ***Pon***: *Poa nemoralis;* ***Pom***: *Polypogon monspeliensis;* ***Roc***: *Rostraria clarkeana;* ***Rop***: *Rostraria pumila;* ***Saf***: *Saccharum filifolium;* ***Sap***: *Saccharum spontaneum;* ***Sci***: *Schizachyrium impressum;* ***Sep***: *Setaria pumila;* ***Soa***: *Sorghum arundinaceum;* ***Son***: *Sorghum nitidum.*

**Table 3. Percentage covers of native grasses at different sites in Neelum Valley.**

| **Plant species** | **Chilhana** | **Jura** | **Kundal Shahi** | **Athmuqam** | **Kairan** | **Nagdar** | **Lawat** | **Dawarain** | **Dodonial** | **Sharda** | **Kail** | **Janawai** | **Sardari** | **Halmat** | **Taobutt** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Agrostis pilosula* | | 🟧 | | 🟨 | | | | | | | | | | | |
| *Agrostis viridis* | | | 🟦 | | | | | | | | | | | | |
| *Apluda mutica* | | | | | 🟨 | 🟧 | | 🟦 | | | | | | 🟨 | 🟧 |
| *Aristida cyanantha* | | 🟨 | | 🟨 | | | | | 🟧 | | | | | | |
| *Aristida funiculata* | | | 🟦 | | | | | | | | | | | 🟧 | |
| *Aristida mutabilis* | | | | 🟧 | | | | | 🟥 | 🟧 | | | 🟨 | | |
| *Arthraxon prionodes* | | | | 🟨 | | 🟧 | | | | | 🟦 | | | 🟨 | 🟨 |
| *Arundinella nepalensis* | | | | | | 🟨 | | | | | | | 🟧 | 🟨 | |
| *Arundinella* sp. | | | | | | | | | | | 🟨 | | | | |
| *Avena byzantina* | | | | 🟨 | | | | | | | | | | | |
| *Avena fatua* | | | | | 🟧 | | | | | | | 🟨 | | | 🟨 |
| *Bothriochloa bladhii* | | | | | | 🟨 | | | | | | 🟩 | 🟧 | | |
| *Bothriochloa pertusa* | | | | | 🟨 | 🟦 | | 🟧 | | | | | | | 🟦 |
| *Brachypodium distachyon* | | | | | | | 🟧 | 🟧 | 🟧 | 🟨 | | | 🟧 | | |
| *Brachypodium* sp. | | | | | | | 🟧 | 🟧 | 🟥 | 🟧 | | | | | |
| *Brachypodium sylvaticum* | 🟧 | | 🟦 | | | | | | | | | | | | |
| *Capillipedium parviflorum* | 🟦 | | 🟧 | | | | | | | | | | | | |
| *Cenchrus pennisetiformis* | | 🟨 | | | | | 🟨 | | 🟥 | 🟨 | | | 🟨 | | |
| *Cenchrus* sp. | | | | 🟨 | | | | | 🟧 | 🟧 | | | 🟨 | | |
| *Cynodon dactylon* | | | | | | | 🟧 | 🟧 | 🟩 | 🟨 | | 🟧 | | | |
| *Digitaria cruciata* | | | 🟦 | | | 🟦 | | 🟩 | | | | | | 🟧 | |
| *Eleusine indica* | | | | | 🟦 | 🟨 | | 🟧 | | | | | | | |
| *Festuca kashmiriana* | | | | | | | 🟧 | | 🟥 | | | | 🟦 | | |
| *Festuca levingei* | | | | | | | 🟧 | | 🟧 | 🟨 | | | | | 🟥 |
| *Festuca simlensis* | | | | 🟧 | | | | | 🟨 | 🟦 | 🟨 | | | 🟨 | |
| *Heteropogon contortus* | | 🟨 | | | | 🟨 | | 🟧 | 🟦 | | | 🟩 | | | 🟧 |
| *Hordeum glaucum* | | | | | 🟨 | | | | | | | | | | |
| *Hordeum marinum* | 🟩 | | | 🟧 | | | | | | | | | | | |
| *Koeleria cristata* | | | | | 🟧 | | | | | | | | | | |
| *Koeleria macrantha* | 🟧 | | | | | 🟩 | | | | | | | | 🟧 | |
| *Lolium perenne* | | | | | | | | 🟧 | | | 🟧 | | | | 🟨 |
| *Lolium temulentum* | | | | | | | 🟧 | | | | 🟦 | | | 🟦 | 🟧 |
| *Milium effusum* | | | | | 🟧 | 🟨 | | | | | | | | | |
| *Panicum atrosanguineum* | | 🟨 | | 🟧 | | | | | | | | 🟧 | 🟨 | | |
| *Panicum decompositum* | | | | | | | | | 🟨 | | | | | 🟨 | 🟨 |
| *Panicum humile* | | 🟨 | | | | | | | | | | 🟦 | | 🟧 | 🟨 |
| *Parapholis incurva* | | 🟨 | | | 🟧 | | | | | | | | | | |
| *Pennisetum orientale* | | | | | | | | | | | 🟧 | | 🟦 | 🟨 | 🟧 |
| *Poa argunensis* | | | | | | | | | 🟧 | 🟦 | | | | | |
| *Poa attenuata* | | | | | | | | | | | | | 🟨 | | |
| *Poa falconeri* | | | | | | | 🟩 | | | 🟧 | | | | | |
| *Poa infirma* | | | | | 🟨 | | | | | | | | | | |
| *Poa nemoralis* | 🟦 | | | | | | | | | | | | | | |
| *Polypogon monspeliensis* | | 🟨 | | 🟦 | | | | | | | 🟨 | | | | |
| *Rostraria clarkeana* | | 🟨 | | | | | 🟧 | | 🟧 | 🟥 | | | | | |
| *Rostraria pumila* | | 🟧 | | 🟧 | | | | 🟧 | | | 🟦 | | | | |
| *Saccharum filifolium* | | | 🟧 | | 🟦 | 🟧 | | 🟧 | | | | | | | 🟨 |
| *Saccharum spontaneum* | 🟦 | | | | | | | | | | | | | | |
| *Schizachyrium impressum* | | | | 🟧 | | | 🟧 | 🟧 | | 🟨 | | | | | |
| *Setaria pumila* | | | 🟦 | | 🟧 | | | | | | | 🟨 | | | |
| *Sorghum arundinaceum* | | 🟨 | | | | | | | 🟥 | | | 🟦 | | | |
| *Sorghum nitidum* | | | | | | | | | | | 🟩 | | | | |

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