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DISTRIBUTION AND ECOLOGY OF SOME *CAREX* L. SPECIES IN SUB-TROPICAL PINE AND HIMALAYAN MOIST TEMPERATE FORESTS

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Abstract

Carex (Family Cyperaceae) resembles superficially with grasses and rushes. This genus primarily is confined to high elevations, and is among the least studied groups in Pakistan. The present study was focused on the investigation of distributional patterns and ecology of genus *Carex* in the chir pine (sub-tropical pine forests) and blue pine (Himalayan moist temperate forests) region. About 40 species were collected from five different sites, namely Ayubia, Bansra Gali, Bhurban, Ghora Gali and Patriata. Species were identified with the help of various herbaria, flora and internet resources. Ecological studies were conducted by the quadrat method, and the quadrats were laid along a transect line. Three species, *Carex ecostata, C. raphidocarpa* and *C. lindleyana,* were the new records in Pakistan. Relative density was the highest in *C. halleriana* at Ayubia (elevation 2380 m). At Bhurban (elevation 1890 m), four species (*C. nubigena, C. atrofusca, C. diandra* and *C. pruinosa*) were recorded more frequently than all other species. At Ghora Galli (elevation 1850 m), species like *C. sanguinea, C. chitralensis and C. turkestanica* were recorded more frequently. No *Carex* species dominated the habitats at Bansra Galli (elevation 1650 m) and Patriata (elevation 1800). Soil physicochemical characteristics showed little variation at all study sites, but variation regarding soil ECe was relatively high. Variation in soil attributes and altitudinal gradients affected the diversity and distributional pattern of *Carex* species in the Himalayan mountains.

Key words: Altitude, *Carex* L., Distribution, Diversity, Soil physicochemical.

Introduction

Cyperaceae is the third largest family of monocots in terms of diversity. It is cosmopolitan in nature and occupies temperate regions of the world. Cyperaceae consists of more than 5,500 species and 104 genera (Govaerts *et al*., 2018). *Carex* L. is the largest genus of family Cyperaceae, primarily distributed in cold to temperate regions of east Africa and north America (Starr *et al.*, 2004; Mabberley, 2008). Major areas flourishing the plants of *Carex* are east Africa and north America. It is also found in Pakistan, India and Southeast Asia, mainly in highlands (Kukkonen, 2001).

Physical environment and climate play a vital role in the distribution of plant species. Analysis of distributional patterns of plant species is of utmost importance in observing the distributional range, origin of particular flora, diversification and evolution. Geographical distributional patterns of plant vegetation provide an understanding of plant diversity and management plans for plant conservation (Qain, 2001).

Carex L. species are mostly vital components of different ecosystems due to their vast diversity, ecological importance and indicators of various habitats (Starr *et al*., 2001). Species of genus *Carex* are important members of dry prairies, flood plain forests, peat lands, alpine meadows, sedge meadows, swamp forests and an extensive range of other communities (Reznicek, 1990).

In Pakistan, 73 species of genus *Carex* are recognized (Kukkonen, 2001; Ullah *et al*., 2013), which cover all four subgenera (*Carex*, *Vignea*, *Indocarex* and *Primocarex*). In Pakistan, genus *Carex* becomes a dominant component of northern and alpine temperate ecosystem (Ullah *et al*., 2013). Stewart (1972) reported approximately 50 species of *Carex* from the Kashmir Himalaya region, which is presently included under the administrative control of China and Pakistan.

Ecologically and botanically the high alpine region of Northern Pakistan is poorly investigated (Khan *et al*., 2013). Thus, the major goal of the present work was to provide a comprehensive study of genus *Carex* that is distributed in the alpine and temperate region of Northern Pakistan. This study would help investigate the soil-plant relationship and distributional range of different species of genus *Carex*. It was hypothesized that variation in altitudinal gradients influenced distributional pattern and ecology of *Carex* species in mountainous region.

Materials and Methods

The present study was conducted to evaluate the ecology and distributional pattern of genus *Carex* in relation to soil physicochemical attributes.

Selection of sites and plant species: Species of genus *Carex* were collected from six different sites (Ayubia, Bansra Gali, Bhurban, Ghora Gali, Patriata and Changa manga) (Fig. 1). Different species were identified appropriately with the help of various flora and herbaria (Flora of Pakistan, Flora of British India and Flora of China, Herbarium of Botany Department, University of Agriculture, Faisalabad).

Ecological data recorded: Five transect lines of 100 m were laid at each study site, each separated by 500 m (Fig. 2). Twenty sets of quadrats (each of 1x1 m) were placed on transect lines, each quadrat separated from the other by 5 m. Relative density, relative frequency, relative cover, and importance values were measured following the method of Greig-Smith (1983).

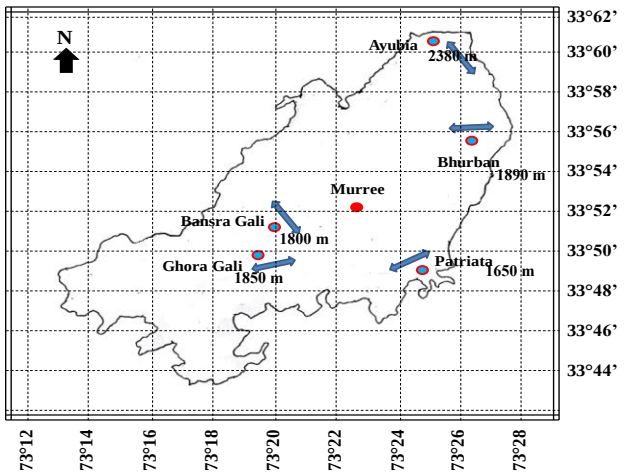


Fig. 1. Map of Murree region showing *Carex* collection sites and average elevation above sea level.

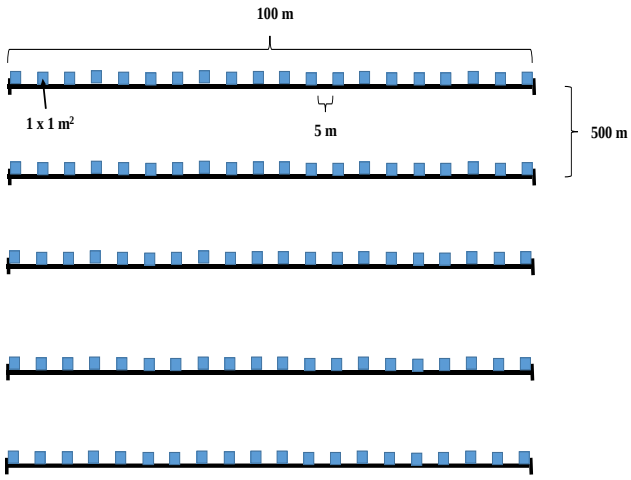


Fig. 2. Layout plan at *Carex* study sites by line transect and quadrat method.

Soil analysis

Soil rhizosphere samples were (16 cm deep) collected from each site to estimate the soil physico-chemical properties following Handbook # 60 (US Salinity Laboratory Staff, 1954). Saturation paste was made from 200 g dried soil samples, and used for analysis of pH, saturation percentage and electrical conductivity. ECe and pH were analyzed using an ECe/pH meter (WTW series Ino LAB pH/Cond 720, USA). Soil Na^+ and K^+ were determined using a flame photometer (Sherwood, 410, UK) by extracting soil samples in deionized water. Inorganic Ca^{2+} was estimated with atomic absorption spectrophotometer ((Model, Analyst 3000: Perkin Elmer, NW, CT).

Statistical analysis

Data were subjected to redundancy analysis (RDA) to evaluate the influence of soil factors on distribution of different *Carex* species along altitudinal gradient.

Results

Soil Physicochemical characteristics: Soil pH value was the maximum at Bansra Galli for *C. canescens and C. cardiolepis* species (Figs. 3 and 4). Species collected from Patriata showed a higher value for pH at *Carex halleriana* habitat. Species of Bhurban site collectively showed lower values for soil pH as compared to the other study sites. *Carex remota* collected from Ghora Galli site exhibited the highest pH value as compared to other species of *Carex*. *Carex halleriana* habitat showed the maximum value of soil pH at Ayubia site (Fig. 5). Saturation percentage was the maximum in the soils of species *C. canescens and C. cardiolepis* at Bansra Galli site. *Carex flacca* habitat showed maximum value for saturation percentage at the Patriata. *Carex nubigena* showed its high value at Bhurban. Species *C. karoi* showed the highest value of soil saturation percentage at both Ghora Galli and Ayubia sites (Fig. 5). ECe values were the highest in species *C. foliosa* at Bansra Galli and Patriata. Species *C. macrogyna* from Bhurban showed high value of soil ECe, while this trait at Ghora Galli site was the maximum in *C. decaulescens*. *Carex karoi* showed the highest value of soil ECe at Ayubia (Fig. 5).

Soil organic matter (%) was the highest in *C. foliosa* at Bansra Galli and Patriata. *Carex diluta* habitat showed the highest value of organic matter at Bhurban. *Carex turkestanica* colonizing Ghora Galli site showed the maximum value of soil organic matter. *Carex haematostoma* habitat showed the highest value for organic matter at Ayubia (Fig. 5).

Soil K^+ was the maximum in *C. royleana* at Bansra Gali habitat. The *C. foliosa* and *C. raphidocarpa* collected from Patriata had the maximum soil K^+ as compared to the habitats of other *Carex* species. *Carex macrogyna* inhibiting Bhurban site showed the highest values of soil K^+. At Ghora Galli site, *C. decaulescens* had highest value of soil K^+. The maximum K^+ was observed at *C. royleana* habitat of Ayubia (Fig. 6).

Soil Ca^{2+} was highest at *C. diandra* habitat from Bansra Galli. The Patriata site showed lower values for Ca^{2+} as compared to other study sites. At Bhurban, *C. macrogyna* showed the highest value for soil Ca^{2+}. At Ghora Galli, *C. diandra* showed the maximum values of soil Ca^{2+}, while *C. arex cruenta* habitat showed the highest value at Ayubia (Fig. 6).

Soil PO_4^{3-} value was the maximum in *C. decaulescens* at Bansra Galli habitat. Species *C. foliosa* collected from Patriata showed higher values of this trait. Species of Bhurban site generally showed lower value of soil PO_4^{3-}. At site Ghora Galli, *C. decaulescens* habitat showed the maximum value of soil PO_4^{3-}. *Carex royleana* habitat showed the highest value of soil PO_4^{3-}, at Ayubia (Fig. 6).

Ecological parameters: *Carex haematostoma* showed the highest value of relative density at site Bansra Galli, while *C. cardiolepis* at Patriata, *C. pruinosa* at Bhurban, *C. sanginea* at Ghora Galli and *C. halleriana* at Ayubia showed the maximum value of relative density (Fig. 7).

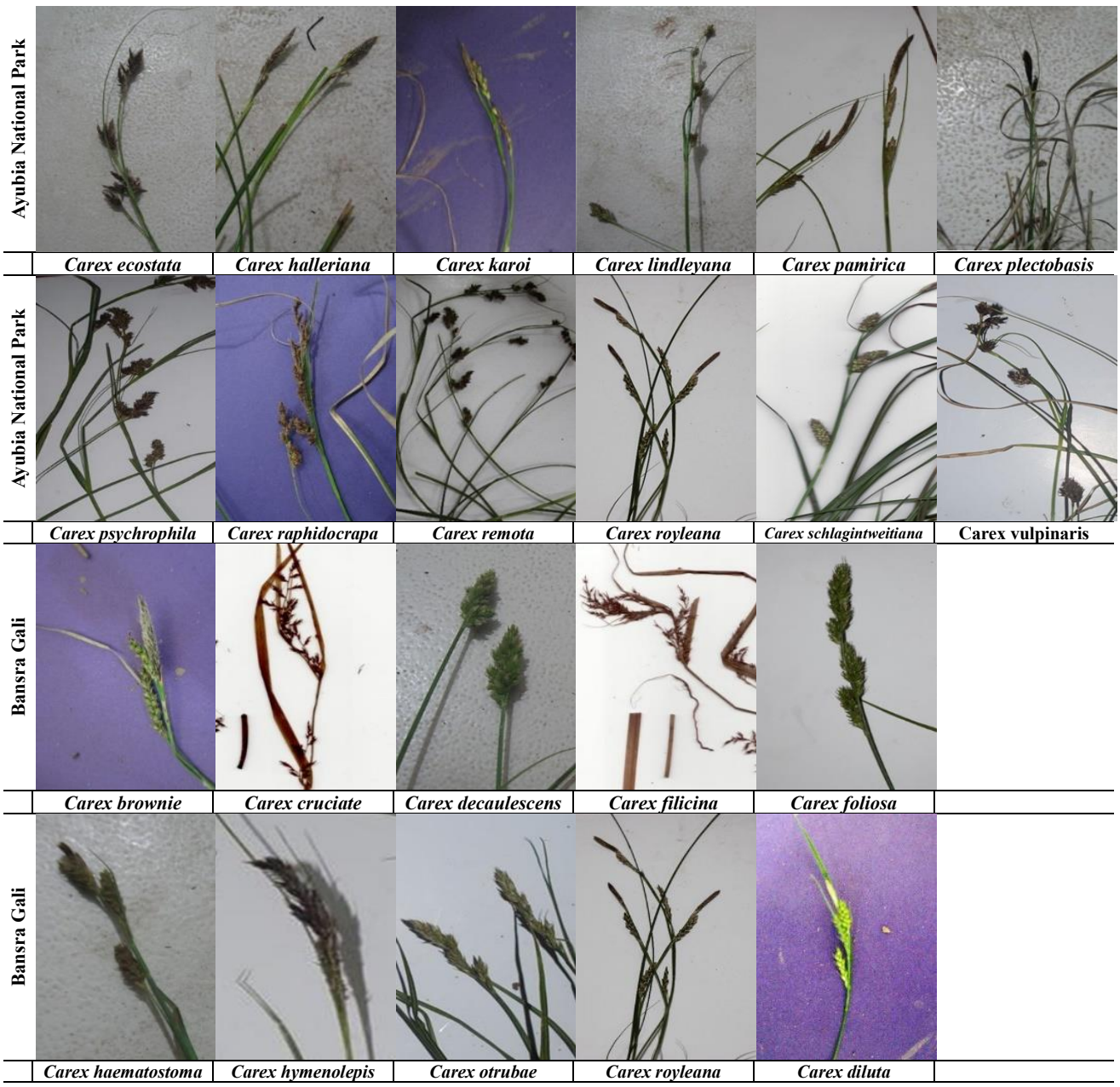


Fig. 3. *Carex* species collected from Changa Manga Forest Plantation, Ayubia National Park and Bansra Galli.

Values of relative frequency were relatively low in the species of Bansra Galli as compared to those at other study sites. *Carex haematostoma* showed the highest value of relative frequency at Patriata, while *C. pruinosa* surpassed all species at Bhurban regarding this attribute. Ghora Galli species *C. turkestanica* and Ayubia species *C. halleriana* showed highest value of relative frequency (Fig. 7). *Carex haematostoma* had the maximum value for relative cover at Bansra Galli site, and *C. cardiolepis* showed the highest value of this trait at Patriate. *Carex pruinosa* showed the maximum values of relative cover at Bhurban site. *Carex turkestanica* showed the highest value of relative cover at Ghora Galli, while *C. halleriana* had the maximum relative cover at Ayubia (Fig. 7).

Carex haematostoma showed the maximum importance value at Bansra Galli. At Patriata, *C. cardiolepis* showed the highest importance value, while at Bhurban, *C. pruinosa* and at Ghora Galli, *C. turkestanica* showed a maximum importance value. *Carex halleriana* showed the highest value of importance value at Ayubia (Fig. 7).

Redundancy analysis (RDA): The RDA biplot ordination demonstrated a significant correlation between soil physicochemical and ecological characteristics of genus *Carex* collected from Bansra Galli (Fig. 8). A strong association was assessed between saturation percentage, pH and relative frequency, but weak association was observed between relative density and soil ECe. *Carex sanguinea* and *C. brownie* strongly associated with each other, while *C. canescens* and *C. vulpinaris* showed negative correlation. A strong association was observed in species of Patriata (Fig. 8). Soil ECe, pH, PO_4^{3-} and organic matter were strongly correlated with each other. *Carex nivalis* and *C. halleriana*, *C. acutiformis* and *C. raphidocarpa* correlated with each other, while rest of species did not show any association.

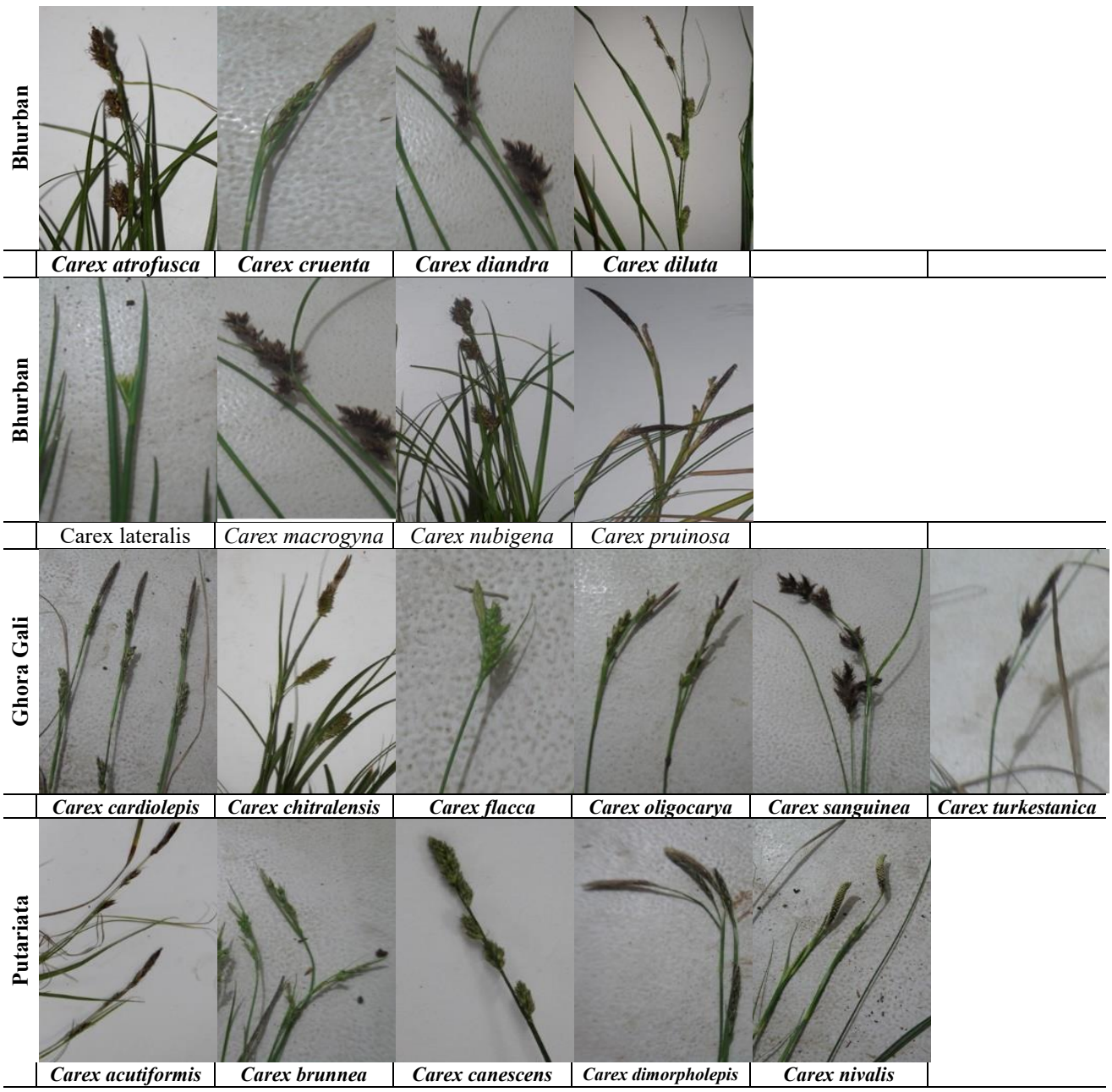


Fig. 4. *Carex* species collected from Bhurban, Ghora Galli and Putriata.

Plant species collected from Bhurban did not show any association and most of them were negatively correlated (Fig. 8). Soil pH and K^+ were negatively correlated, while organic matter and ECe were significantly related to each other. Soil physicochemical traits like saturation percentage, Ca^{2+}, K^+ and pH were strongly associated, while *C. diandra* and *C. karoi* were positively related to each other at Ghora Galli (Fig. 8). Soil K^+ were significantly correlated with relative frequency, pH and saturation percentage at Ayubia (Fig. 8).

Discussion

Carex species diversity was high, as 41 species were recorded from the study area. Distributional range, however, was limited in the Punjab region, as reported by Öztürk *et al*., (2015). Three species, *C. raphidocarpa*, *C. lindleyana* and *C. ecostata,* were the first record in Pakistan, however, these species were reported in Hooke Flora of British India (Clarke, 1893).

Ayubia was the highest elevation (2200-2300 m a.s.l.), located at the Punjab and Khyber Pakhtoonkhwa border. The slope of the mountains was steep, i.e., more than 60°. Species diversity was quite high, where 17 *Carex* species were recorded from the area, many restricted to this site only. Dominant species at Ayubia were also specific. Two species (*Carex lindleyana.* and *Carex ecostata*) among the new record that colonized the Ayubia site. Ayubia receives frequent and heavy snowfall during winters (Afza *et al*., 2016), and this resulted in the occurrence of these specific species, that were not recorded at any other site.

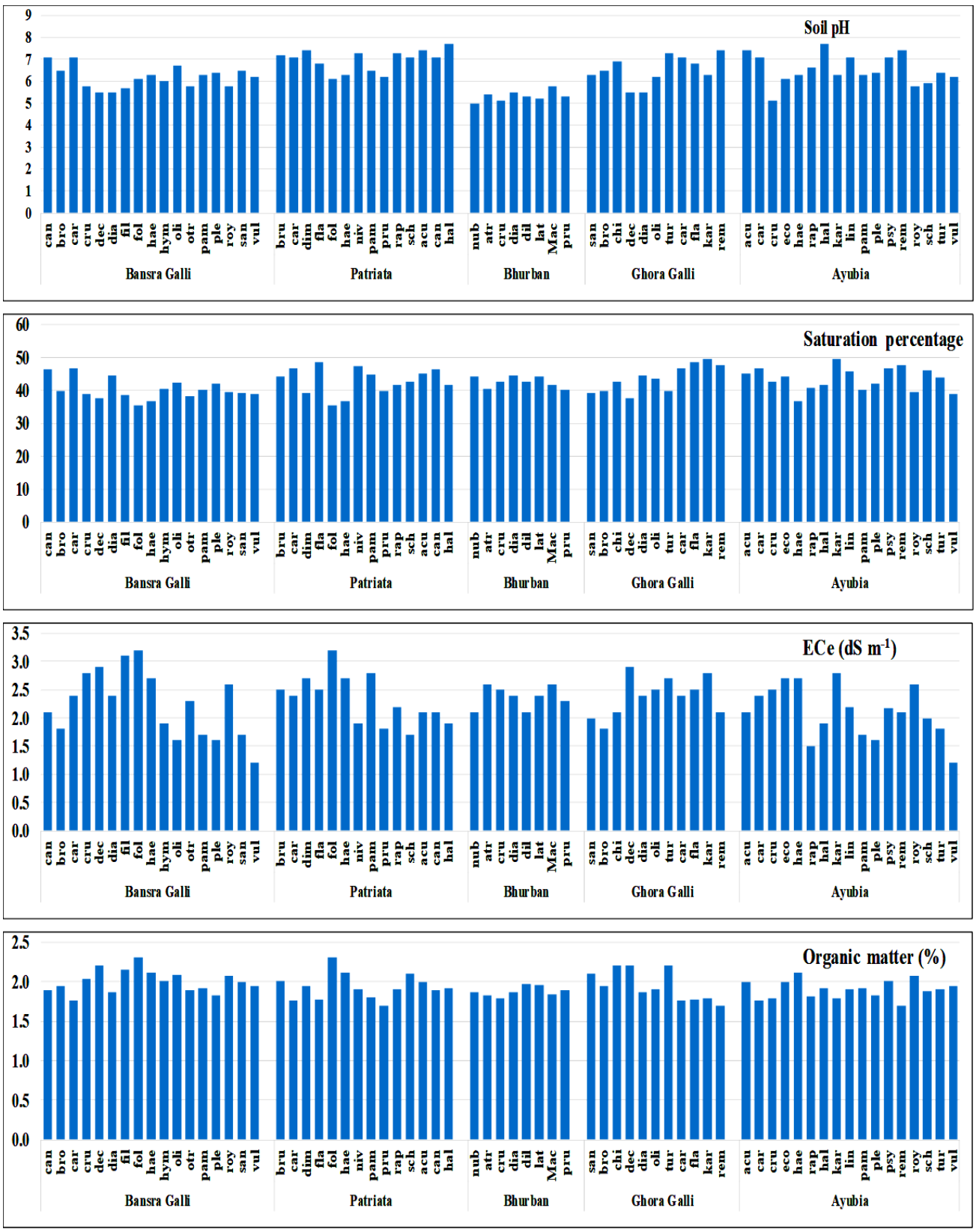


Fig. 5. Soil physicochemical characteristics (pH, ECe, SP and OM) of genus *Carex* collection sites.
acu-Carex acutiformis, atr-Carex atrofusca, bro-Carex brownie, bru-Carex brunnea, can-Carex canescens, car-Carex cardiolepis, chi-Carex chitralensis, cru-Carex cruciate, cru-Carex cruenta, cru-Carex cruenta, dec-Carex decaulescens, dia-Carex diandra, dia-Carex diandra, dil-Carex diluta, dim-Carex dimorpholepis, eco-Carex ecostata, fil-Carex filicina, fla-Carex flacca, fol-Carex foliosa, hae-Carex haematostoma, hal-Carex halleriana, hym-Carex hymenolepis, kar-Carex karoi, kar-Carex karoi, lat-Carex lateralis, lin-Carex lindleyana, mac-Carex macrogyna, niv-Carex nivalis, nub-Carex nubigena, oli-Carex oligocarya, otr-Carex otrubae, pam-Carex pamirica, ple-Carex plectobasis, pru-Carex pruinosa, psy-Carex psychrophila, rap-Carex raphidocarpa, rem-Carex remota, roy-Carex royleana, san-Carex sanguinea, sch-Carex schlagintweitiana, tur-Carex turkestanica, vul-Carex vulpinaris.

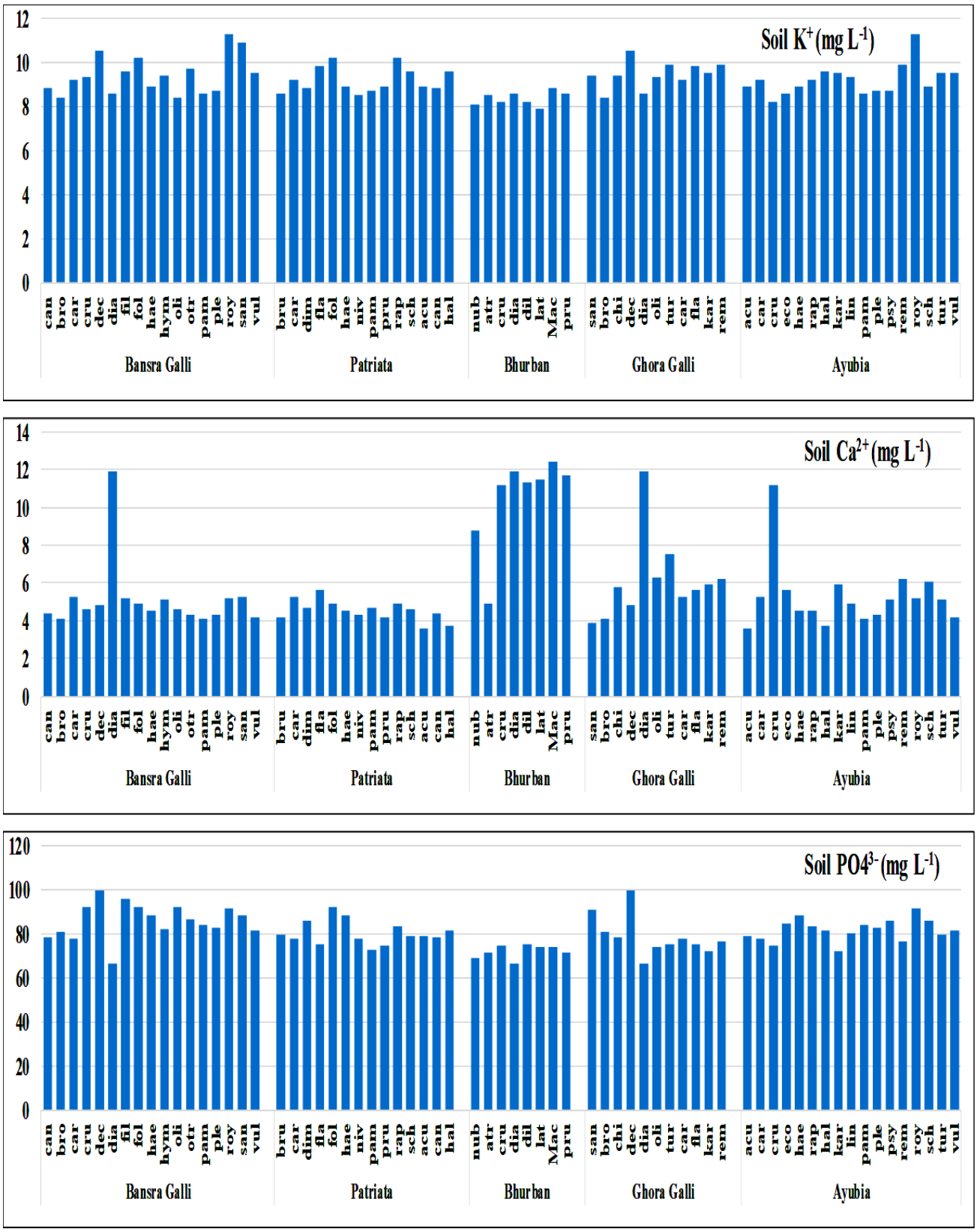


Fig. 6. Soil physicochemical characteristics (ionic content) of genus *Carex* collection sites.
acu-Carex acutiformis, atr-Carex atrofusca, bro-Carex brownie, bru-Carex brunnea, can-Carex canescens, car-Carex cardiolepis, chi-Carex chitralensis, cru-Carex cruciate, cru-Carex cruenta, cru-Carex cruenta, dec-Carex decaulescens, dia-Carex diandra, dia-Carex diandra, dil-Carex diluta, dim-Carex dimorpholepis, eco-Carex ecostata, fil-Carex filicina, fla-Carex flacca, fol-Carex foliosa, hae-Carex haematostoma, hal-Carex halleriana, hym-Carex hymenolepis, kar-Carex karoi, kar-Carex karoi, lat-Carex lateralis, lin-Carex lindleyana, mac-Carex macrogyna, niv-Carex nivalis, nub-Carex nubigena, oli-Carex oligocarya, otr-Carex otrubae, pam-Carex pamirica, ple-Carex plectobasis, pru-Carex pruinosa, psy-Carex psychrophila, rap-Carex raphidocarpa, rem-Carex remota, roy-Carex royleana, san-Carex sanguinea, sch-Carex schlagintweitiana, tur-Carex turkestanica, vul-Carex vulpinaris.

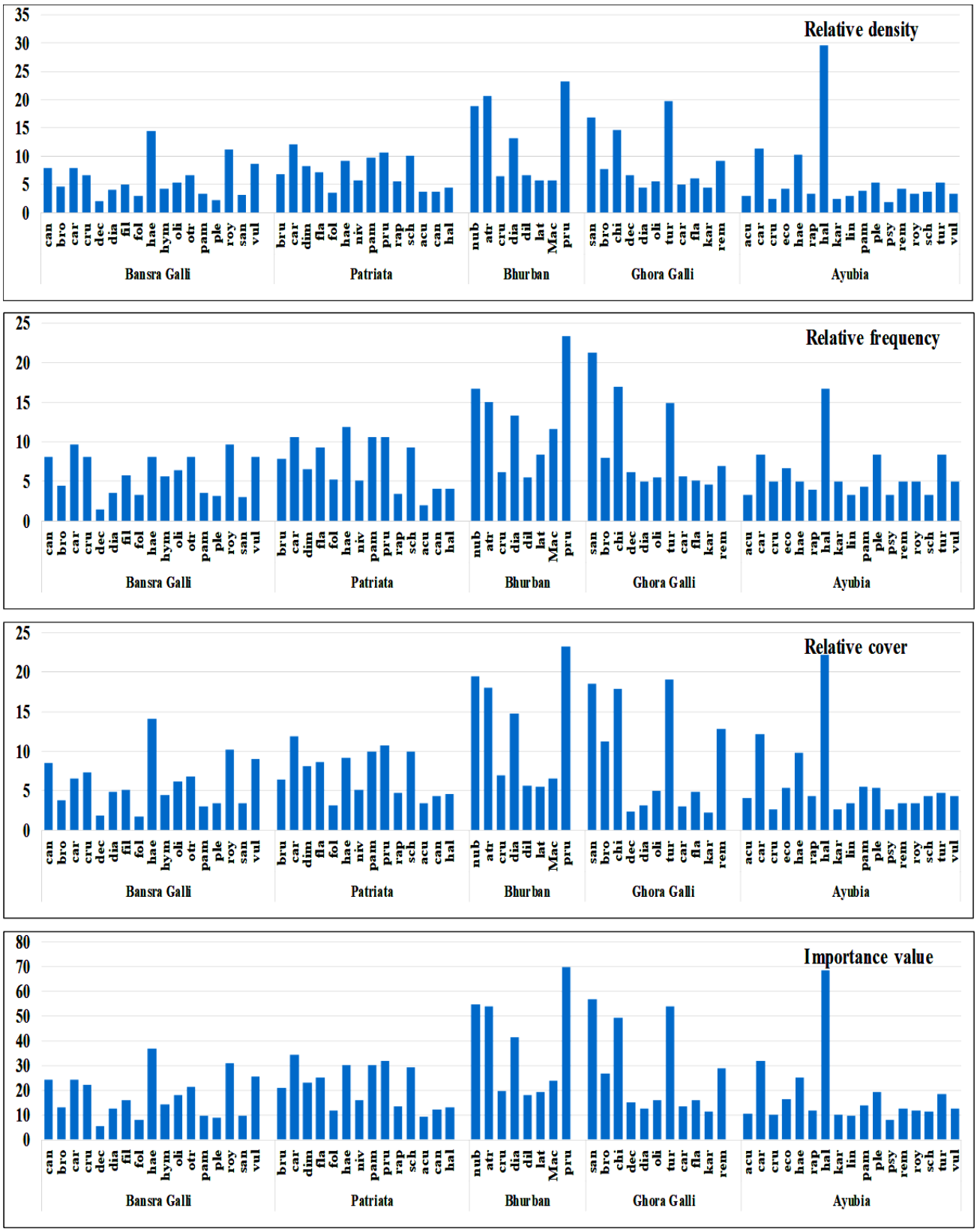
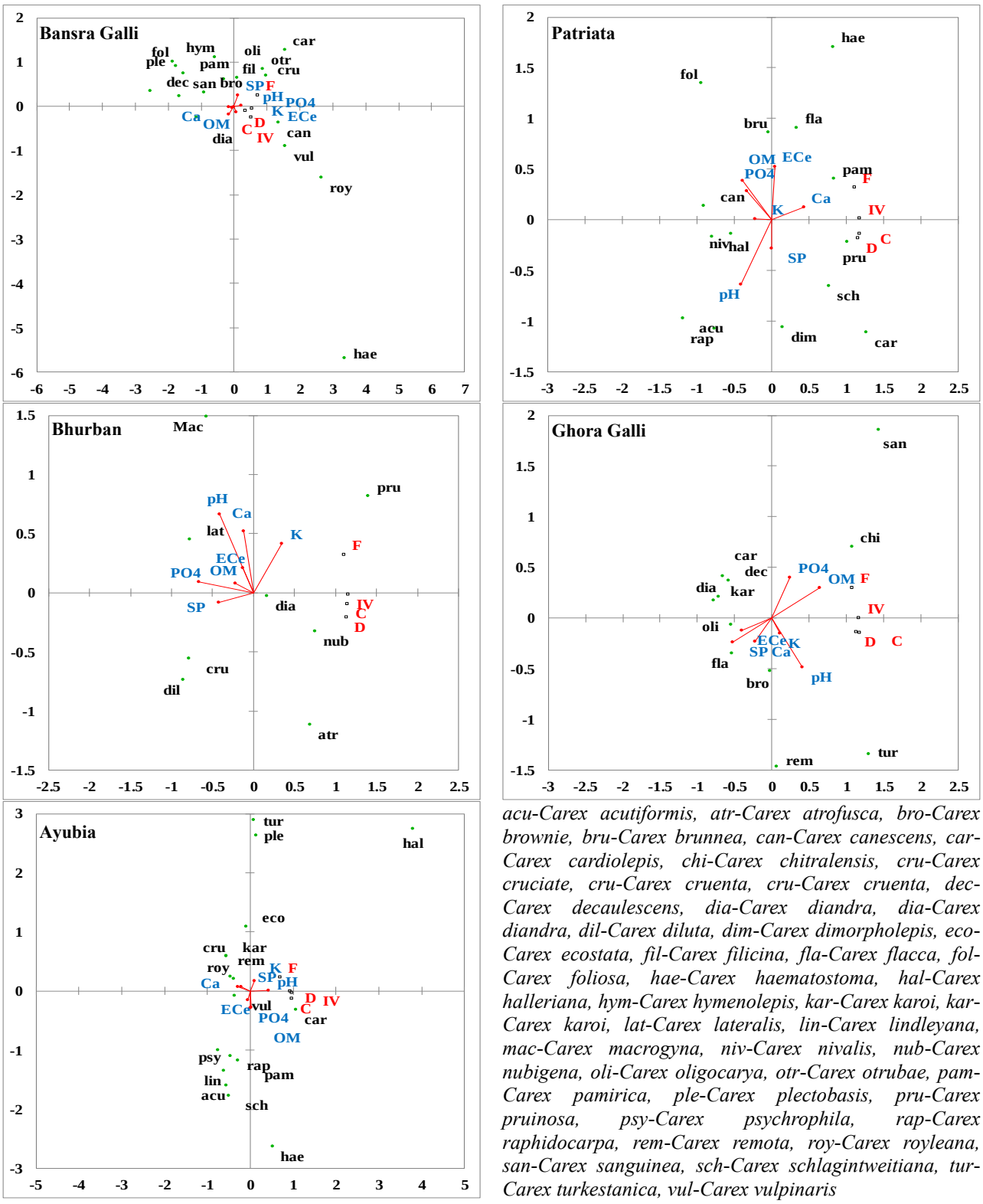


Fig. 7. Ecological parameters of genus *Carex* collected from different sites

acu-Carex acutiformis, atr-Carex atrofusca, bro-Carex brownie, bru-Carex brunnea, can-Carex canescens, car-Carex cardiolepis, chi-Carex chitralensis, cru-Carex cruciata, cru-Carex cruenta, cru-Carex cruenta, dec-Carex decaulescens, dia-Carex diandra, dil-Carex diluta, dim-Carex dimorpholepis, eco-Carex ecostata, fil-Carex filicina, fla-Carex flacca, fol-Carex foliosa, hae-Carex haematostoma, hal-Carex halleriana, hym-Carex hymenolepis, kar-Carex karoi, kar-Carex karoi, lat-Carex lateralis, lin-Carex lindleyana, mac-Carex macrogyna, niv-Carex nivalis, nub-Carex nubigena, oli-Carex oligocarya, otr-Carex otrubae, pam-Carex pamirica, ple-Carex plectobasis, pru-Carex pruinosa, psy-Carex psychrophila, rap-Carex raphidocarpa, rem-Carex remota, roy-Carex royleana, san-Carex sanguinea, sch-Carex schlagintweitiana, tur-Carex turkestanica, vul-Carex vulpinaris.



acu-Carex acutiformis, atr-Carex atrofusca, bro-Carex brownie, bru-Carex brunnea, can-Carex canescens, car-Carex cardiolepis, chi-Carex chitralensis, cru-Carex cruciate, cru-Carex cruenta, cru-Carex cruenta, dec-Carex decaulescens, dia-Carex diandra, dia-Carex diandra, dil-Carex diluta, dim-Carex dimorpholepis, eco-Carex ecostata, fil-Carex filicina, fla-Carex flacca, fol-Carex foliosa, hae-Carex haematostoma, hal-Carex halleriana, hym-Carex hymenolepis, kar-Carex karoi, kar-Carex karoi, lat-Carex lateralis, lin-Carex lindleyana, mac-Carex macrogyna, niv-Carex nivalis, nub-Carex nubigena, oli-Carex oligocarya, otr-Carex otrubae, pam-Carex pamirica, ple-Carex plectobasis, pru-Carex pruinosa, psy-Carex psychrophila, rap-Carex raphidocarpa, rem-Carex remota, roy-Carex royleana, san-Carex sanguinea, sch-Carex schlagintweitiana, tur-Carex turkestanica, vul-Carex vulpinaris

Fig. 8. Relationship between soil physicochemical and ecological characteristics of *Carex* species collected from different sites.

Altitudinal range of Patriata was between 2100-2200 m a.s.l., which was characterized by steep slopes and flat hill tops. A total of 14 *Carex* species were recorded from the area. Five species, *C. canescens, C. brunea, C. dimorpholepis, C. nivalis* and *C. foliosa* were restricted to that site. Annual snowfall is quite higher than the adjacent areas like Bhurban, Ghora Galli and Bansra Galli.

Altitudinal range at Ghora Galli is from 1900 to 2000 m a.s.l.; 11 species were recorded at this site. *Carex chitralensis* was exclusively recorded from this site. The mountains at this site had moderate to steep slope ranging from 45-60°. Species diversity was quite high at Bansra Galli, where 17 species were recorded. Four species, *C. filicina, C. otrubae*, *C. cruciata* and *C. hymenolepis* restricted to this site only.

Diversity of *Carex* species was the least at Bhurban, where 8 species were recorded. Five species were found only at this site, which were *C. macrogyna*, *C. atrofusca, C. lateralis, C. diluta,* and *C. nubigena.* Altitudinal range was the lowest, ranging between 1700 to 1800 m a.s.l., and this resulted in a very specific species composition regarding *Carex* species. Slopes were quite steep, i.e., more than 60° at many places.

Soil parameters significantly altered along the elevation gradient (Dai and Huang, 2006), as were recorded in the present study. Rhizospheric soil pH at Bhurban (lower altitudes) showed the minimum value, which was associated with species like *C. macrogyna* and *C, lateralis.* Lekhendra *et al.*, (2015) and Decker and Boerner (2003), however, reported reduction in organic matter, soil nutrients, organic matter and pH along the elevation gradient (Khan & Qaiser, 2006). Low value of soil ECe was apparently associated with *Carex* species like *C. vulpinaris* and *C. raphidocarpa,* indicating their low degree of salt tolerance. Similar findings have earlier been reported by Saeed *et al.,* (2014), who studied soil characteristics from Quetta region. In our case, soil parameters showed no definite trend with increase in altitude. The study area is greatly diverse regarding aspect, soil availability and slopes. *Carex* species occupied nutrient resources of this area and hence, as a result, they dominated specific sites. This patchy distribution ultimately altered soil characteristics as have also been reported by Aerts and De Caluwe (1990) and Ohlson & Malmer (1990).

Conclusion

The present study concludes that species of *Carex* respond differently in terms of soil physico-chemical characteristics and ecological traits. These species colonized different habitats from hilly areas to plain area and different altitudinal gradients. New records in Pakistan were reported in the region, and many more could be expected if the studies expand to other areas of Pakistan.

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