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IMPROVEMENT IN FERTILITY OF NUTRITIONALLY POOR SANDY SOIL OF CHOLISTAN DESERT, PAKISTAN BY *CALLIGONUM POLYGONOIDES* LINN.

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Abstract

The study was undertaken in Cholistan desert of Pakistan, with the objective of quantifying differences in soil nutrient status under *Calligonum polygonoides* canopies (canopied subhabitat) in comparison to the open area (uncanopied subhabitat). The results of the study clearly showed the existence of differences in the soil nutrient status between the various subhabitats, which occurred at various places from stem base area of the plant towards the open, uncanopied area. The results confirmed that electrical conductivity, nitrogen, organic matter, potassium, calcium, magnesium, sulphur, phosphorus, carbonates and bicarbonates were significantly high in the soils under the canopy cover of the plant as compared to those in uncanopied area (open area) but pH value was comparatively low in the soils under the canopy cover of the plant. It is evident from the results that canopy cover of *C. polygonoides* is playing a significant role in enrichment of nutrient poor soils of Cholistan desert.

Introduction

Calligonum polygonoides, locally known as "Phog" belongs to family Polygonaceae. Polygonaceae is a family of 55 genera and possibly over 1150 species, mostly distributed in temperate regions, particularly in the northern hemisphere, represented in Pakistan by 19 genera and 103 species. *C. polygonoides* is a small shrub, found in Southern Baluchistan, Trans-Indus plains, Thar and Cholistan desert areas. Species available in Cholistan desert is *Calligonum polygonoides* Linn. It is usually 1 to 2 m high but occasionally may reach even 3 m in height with a girth of 30 to 60 cm (Jussieu, 2001). It commonly grows on dry sandy soils and on sand dunes. It is capable of growing under adverse conditions of soil and moisture (Khan, 1977). The floral buds of this plant are picked during February and March and are cooked as vegetable and eaten with buttermilk and salt (Saxena, 1979; Rao *et. al*., 1989). It is the common woody plant species of the desert region where inhabitants depend on it for energy and fodder supply. Its roots are used to prepare charcoal to melt iron (Singh, 2004).

The vegetation plays very important role in enrichment of nutrient poor sandy soil. The effects of individual trees and shrubs on soil have been investigated in a wide variety of ecosystems (Belsky *et al*., 1989; Garcia & McKell, 1970; Kellman, 1979). These studies found that plant species increase the fertility of the soils under their canopies. In addition, plants may also alter the soil microclimate. Most of the studies have been carried out in arid and semi-arid areas and in most cases under canopies of specific plant species.

C. polygonoides is a dominant plant species at sand dunes and interdunal sandy area of Cholistan desert. Enrichment of soil by *C. polygonoides* is suspected to occur and such enrichment will be of sustainable significance in view of improving the low nutrient status of the sandy soil that is commonly found in the Cholistan desert. This study was undertaken to find out the role of *C. polygonoides* in soil enrichment by quantifying differences in soil nutrient status under canopies (canopied subhabitat) in comparison to the open area (uncanopied subhabitat).

Material and Methods

Study area: The study was conducted in Cholistan desert of Pakistan. Cholistan desert, an extension of the Great Indian Desert, is located in southern Punjab of Pakistan, between 27º 42' and 29º 45' north and 69º 52' and 73º 05' east (Akbar *et al*., 1996; Akhter & Arshad, 2006). The climate of Cholistan desert is characterized by low and sporadic rainfall. The mean annual rainfall varies from less than 100 mm in the west to 200 mm in the east. Rain usually falls during monsoon (July through September), winter and spring (January through March). Aridity is the most striking feature of the Cholistan desert with wet and dry years occurring in clusters. (Akhter & Arshad, 2006). Cholistan is one of the hottest regions of Pakistan. Temperatures are high in summer and mild in winter. The mean summer temperature (May, June) is 34ºC with the highest reaching above 51ºC (Mughal, 1997; Akhter & Arshad, 2006).

The vegetation of Cholistan desert is xeric, adapted to extremely high temperature, low moisture contents and increased salinity coupled with wide variation of edaphic factors (Rao *et. al*., 1989; Arshad *et al*., 2006). Fortunately, a wide range of nutritious and drought tolerant species of grasses, shrubs and trees grow in this desert. Important genera of grasses/sedges include *Cenchrus*, *Lasiurus*, *Ochthochloa*, *Panicum*, *Sporobolus*, *Aeluropus*, *Stipagrostis*, *Cymbopogon* and *Cyperus*. Major shrubs include *Calligonum*, *Capparis*, *Leptadinia*, *Acacia*, *Suaeda*, *Aerva* and *Haloxylon*. *Prosopis*, *Zizyphus*, *Tamarix*, *Salvadora* and *Acacia* are notable indigenous tree species (Rao *et al*., 1989, Akther & Arshad, 2006). Main soil types of Cholistan desert are sand dunes (44%), sandy soils (37%), loamy soils (2%) and saline-sodic clayey soils (17%). (Rao *et al*., 1989; Anon., 1993; Akbar & Arshad, 2000).

Subhabitats: With little modification following the methods described by Smit & Swart (1994) and Hagos & Smit (2005) three subhabitats were established. The first subhabitat was located in the open area between the plant canopies (open area). The canopied habitats were taken as the area surrounding the stem base area (around stem), 50 cm away from the stem base area (under canopy-1) and 100 cm away from the stem base area (under canopy-2), but still under the overhead canopy spread of the plant.

Soil sampling: Soil sampling was carried out during June 2006. A quadrate measuring 25 cm × 25 cm was used to excavate a volume of topsoil upto 5 cm deep, from each subhabitat of the plant. The soil from each excavation was thoroughly mixed and a sample was taken for analysis.

Soil analysis: Soil analysis was conducted in the Analytical chemistry laboratory of the Department of Chemistry, the Islamia University of Bahawalpur, Pakistan. Soil pH, electrical conductivity, total nitrogen, organic matter, sulphur, phosphorus, carbonates, bicarbonates and exchangeable cations, i.e., sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) contents were determined by using standard procedures (Anon., 1984). Each analysis was done in triplicate to verify the results and averages were used for further steps.

Results

The mean pH of the soil collected from various subhabitats is given in Fig. 1. Its minimum value was noted at under canopy-1 area. Under the canopy of the plant the pH was decreasing as compared to the open area, but none of the subhabitats differed significantly. Electrical conductivity recorded in the soil under the canopy cover of *C. polygonoides* and in open area is given in Fig. 2. Over all electrical conductivity was decreasing in the soil as compared to that around the stem of the plant towards open area.

The mean N content recorded in the soil of various subhabitats is shown in Fig. 3. As expected, all sandy soils contained low N content but as compared to the open area the nitrogen concentration in the soils at under canopy of the plant was in increasing order.

Organic matter (%) noted in the soil collected from the various subhabitats is shown in Fig. 4. Similar to N contents, the % organic matter contents were generally low. But there was a decreasing trend in the concentration of organic matter in soil from around the stem to under the canopy of the plant.

The mean S and P concentration of the soil collected from four subhabitats is shown in Fig. 5 and 6, respectively. As compared to open area there was an increase in S and P contents under the canopy cover of the plant. Highest S concentration was recorded around the stem base and under canopy-1, which declined linearly towards the open area.

The mean CO_3 and HCO_3 contents recorded in the soil collected from various subhabitats is shown in Fig. 7 and 8. Overall, very low concentration of carbonate was recorded but there was a slight increasing trend in carbonates and bicarbonates content in the soil under the canopy cover of the plants.

The results of exchangeable cation variables of soil (Na, K, Ca, Mg) are given in Figs. 9 a, b, c and d. In all the four cations almost same pattern was recorded i.e., the highest concentration of these cations was noted around the stem base of the plant and declined towards the open and uncanopied area.

Discussion

Nutrients, such as nitrogen, phosphorus, a series of anions and cations and various trace elements are essential for plants nutrition (Bell, 1982), and act as determinants of the composition, structure and productivity of vegetation. While the base richness of the parent material is initially important in determining soil fertility and biological activities which in turn essential for creation and maintenance of localized areas of enhanced soil fertility, often on base-poor substrates (Scholes,1991). Soil physical properties are usually recognized as important soil quality indicators. In arid and semi arid ecosystems, where variation in spatial and temporal availability of water and nutrients is at extreme, dominant woody plants cause changes in micro-climate and soil properties that lead to complex local interactions between vegetation and soil (Wilson & Agnew, 1992).

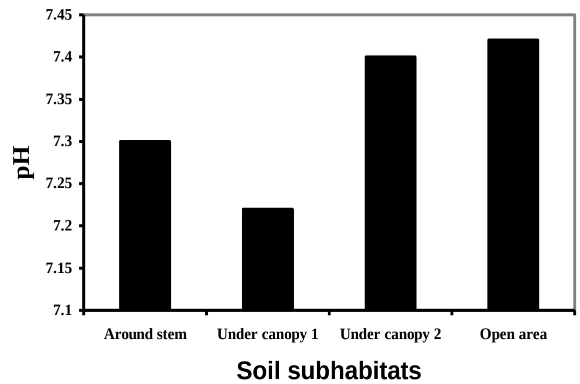

Fig. 1. Soil pH of the four defined subhabitats.

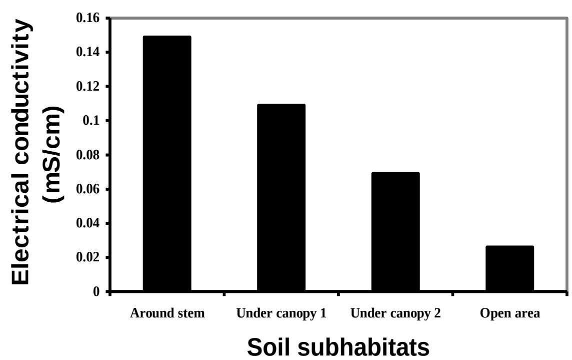

Fig. 2. Soil Electrical; conductivity of soil from the four defined subhabitats.

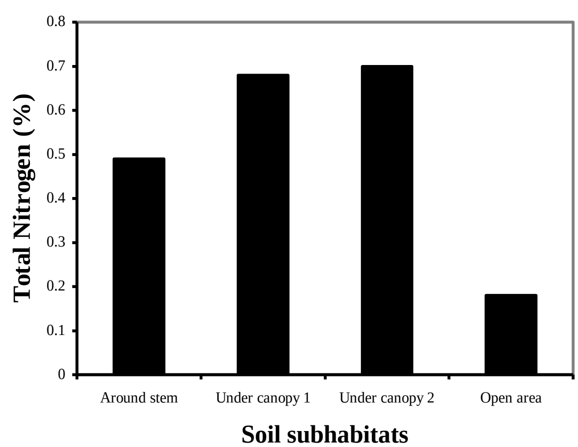

Fig. 3. Nitrogen content of soil from the four defined subhabitats.

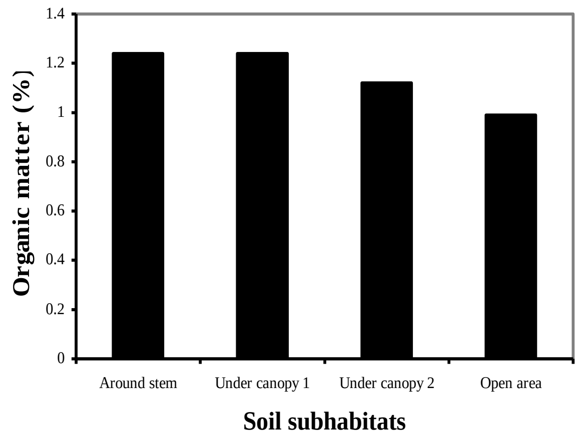

Fig. 4. Organic matter of soil from the four defined subhabitats.

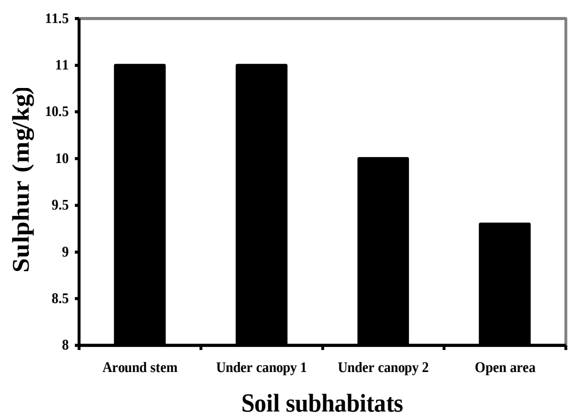

Fig. 5. Suphur content of soil from the four defined subhabitats.

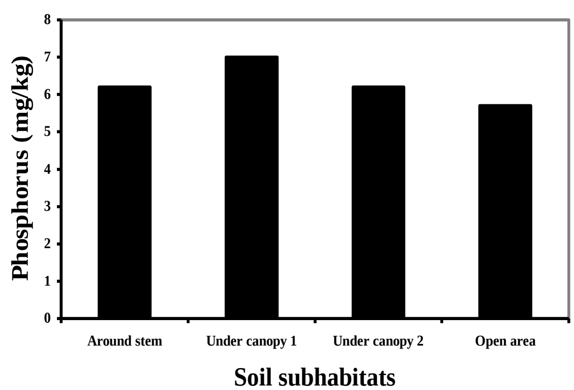

Fig. 6. Phosphorus content of soil from the four defined subhabitats.

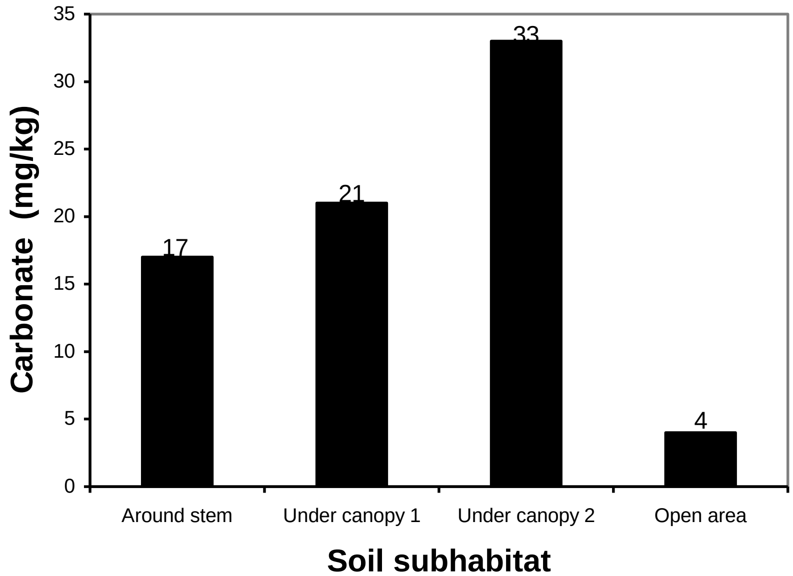

Fig. 7. Carbonate concentration of soil from the four defined subhabitats.

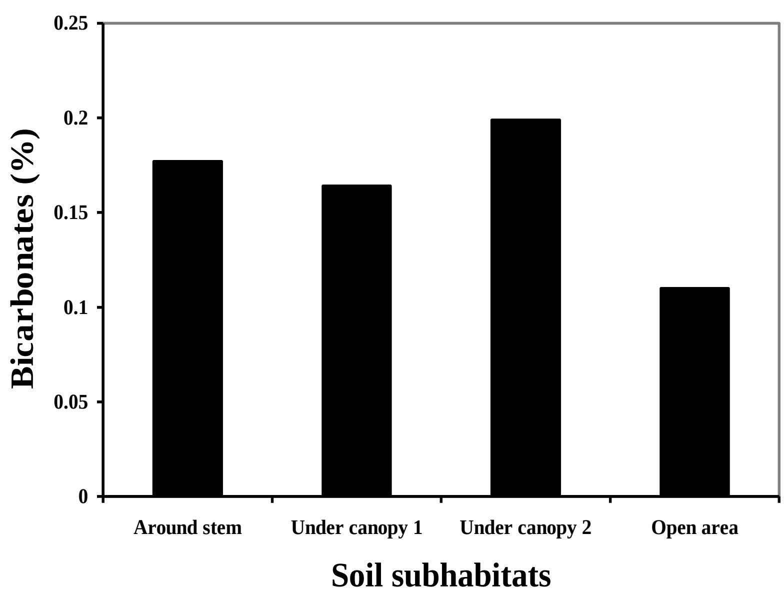

Fig. 8. Bicarbonate concentrations of soil from the four defined subhabitats.

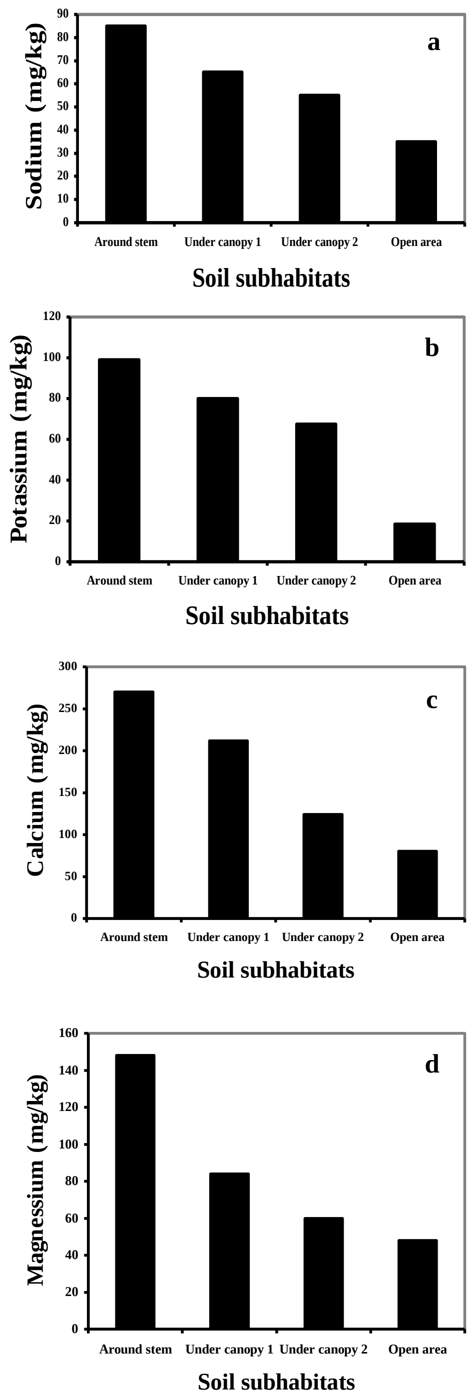

Fig. 9. Results of mean exchangeable cation content of soils from defined subhabitats (a = Na, b = K, c = Ca, d = Mg)

The results described in present study showed that under the canopy cover of *C. polygonoides* an increasing trend in organic matter, electrical conductivity, nitrogen, sodium, potassium, calcium, magnesium, sulphur, phosphorus, chlorides and bicarbonates was recorded as compared to the open area. Similar results have been documented by Isichei & Muoghalu (1992), determining the effects of tree canopy cover on soil fertility in Nigerian Savanna. According to their results all properties were lower in the open than under tree canopies and a high proportion of these differences were significant. The mean contents of the exchangeable cations including calcium, magnesium, potassium and sodium in soils under tree canopies were higher than that in the open area.

Results of Breemen & Finzi, (1998); Hirobe & Ohte, (2001); Bhark & Small, (2003); Titus *et al*., (2002) also confirmed the existence of differences in the soil nutrient status between the various sub-habitats and concluded the presence of plants strongly influenced microsite soil characteristics which results in higher nutrients levels that are exactly comparable to the results of present study.

Several other researchers Moro *et al*., (1997); Belsky *et al*., (1989); Bernhard-Reversat, (1982); Hattan & Smart, (19840; Kellman, (1979); Tiedemann & Klemmedson, (1973) have also reported the similar results under the canopy of plants as compared to that found in open areas. The authors reported that increase in organic matter in the soils under the canopy of plant may be the result of higher organic matter production by the plants and slower rate of its mineralization under the tree canopies due to reduction in temperature. Leachates from tree canopies, nutrient inputs from leaf litter and nutrient transport by tree roots from rooting zones to tree canopies may also be the sources of nutrients supply under tree canopies.

Hagos & Smit, (2005) reported significantly high concentrations of nitrogen, calcium and organic matter in the soil under the canopy cover of *Acacia mellifera* subsp. *Detinens* and confirmed the existence of differences in the soil nutrient status between the various sub habitats, which occurred in a specific spatial gradient from the stem base of the plants towards the open uncanopied areas.

The vegetation influence the physico-chemical properties of soil by releasing hydrogen ions in the soils (soil acidification) or modification of the moisture contents of the soil due to the effect of exudates from roots or little degradation in the soil due to leakage of organic leachates from decaying foliage or litter (Garcia & Mckell, 1970; Garner & Steinberger, 1989).

Under the canopy of the woody plants the process of soil enrichment was demonstrated by Belsky *et al*., (1989) in a semi-arid savanna of Kenya. The result of this study, with the highest nutrient status in soil close to stem, support the findings of the present study.

In present study low pH value was recorded in canopied area of *C. polygonoides* as compared to the uncanopied area (open area). Concentration of carbonates was low around the stem base area of plants which increased towards the edge of the canopy cover of plants (under canopy-2).

The low pH of soil under the plant canopy may be due to the production of highly acidic, slowly decomposing leaf litter containing high lignin and tannin contents (White, 1986, 1991). Reduced soil pH in rhizosphere also contributed in improving organic P mineralization by increasing the susceptibility of organic P to enzymatic hydrolysis (Adams & Pate, 1992; George *et al*., 2002).

The mechanism of soil enrichment under the plant canopies need explanations. A number of theories have been presented by different scientists. Stemflow and leaf litter represent a source of mineral input to soil (Williams *et al*., 1987; Potter, 1992). Leaf litter after leaf fall has also been mentioned as a possible source (Bosch & Van Wyk, 1970; Stuart Hill *et al*., 1987; Belsky *et al*., 1994). Structural differences in leaves of micropyllous and broad leaved plants present a possible source of differences in the amount of leaves reaching to the soil under plant canopies (Smit & Swart, 1994).

Conclusion

The results of this study clearly demonstrate the existence of the differences in the nutrient level of soil under the canopy of *C. polygonoides* in comparison to the soil of open, uncanopied area. Differences appear to occur in relation to a specific spatial gradient from the stem base of the plant to the open canopied areas. Comparing the results of similar studies as reported in literature it can be concluded that *C. polygonoides,* a dominant shrub species of Cholistan desert, act as biological agent to facilitate the enrichment of the nutrient poor sandy soil of Cholistan desert.

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