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EFFECT OF CANOPY COVER OF *CAPPARIS DECIDUA* FORSK. ON SOIL CONDITIONS IN THAL DESERT

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ABSTRACT

Desert shrubs have a deep root system which allows them to explore the soil minerals and moisture from deeper horizons of soil and strongly support the local dwellers' livelihoods. *Capparis decidua* (Forsk.) Edgew, generally known as karir, a xerophytic, densely branched shrub, is widely found in arid and semi-arid areas of Pakistan. The present study was conducted at four different sites in the Thal desert to determine the canopy effect of *C. decidua* on soil nutrients. Soil nutrients under the plant canopy (UC), at a distance of 150 cm away from the canopy (D150) and 300 cm away from the canopy area (D300) were determined. Data revealed that the soil nutrient status was higher in UC soils than the soils of (D150) and (D300). Levels of soil NPK in UC soil vs soils of D150 and D300 was: Nitrogen (N) = 0.49% vs 0.41% & 0.34%; Phosphorus (P) = 7.2 mg/L vs. 6.1 mg/L & 5.3 mg/L; Potassium (K) = 104 mg/L vs 91 mg/L & 83 mg/L. Similarly, soil organic matter (OM) = 1.25% vs 1.05% & 0.83%; sulphur (S) = 8.75 mg/L vs. 8.09 mg/L & 7.19 mg/L. Conversely, carbonates (CO_3^{--}), Bicarbonates (HCO_3^-), and pH were lowest in UC soil, as values of CO_3^{--}, HCO_3^- and pH in UC soil were < D150 < D300. The noted values of CO_3^{--} in UC soil (0.52 meq/L) < D150 soils (0.67 meq/L) < D300 soils (0.94 meq/L); HCO_3^- in UC soil (42.80 meq/L) < D150 soils (45.85 meq/L) < D300 soils (53.10 meq L^{-1}); pH^- in UC soil (7.19) < D150 soils (7.26) < D300 soils (7.41) explained well this pattern. It was concluded that *C. decidua* improved the nutrient deprived sandy soils by enhancing the soil nutrient level.

Keywords: Thal desert, *Capparis decidua*, Canopy cover, Soil nutrients, soil fertility, NPK.

INTRODUCTION

Rangelands are a variety of lands which support natural flora like shrubs, grasses, and forbs, and provide habitats both to local flora and fauna which have soaring worth for both recreation and scientific use. Rangelands cover almost 50% of the biosphere and provide around 70% of feeding essentials of native ruminants worldwide (Holechek *et al*., 1998; Friedel *et al*., 2000).

The total area of Pakistan is about 79.6 million hectares, out of which 65.6% (52.2 million hectares) is under rangelands. Only 18.5 million hectares is cultivated and used for livestock browsing and grazing (Quraishi, 2005). For sustaining the environmental solidity in the country, range flora is of prime importance (Sultani *et al*., 1985). Range areas of Pakistan are providing 40-60% of the fodder requirements for different types of livestock. Because of the severe land degradation and increase in drought, the production of range areas in Pakistan has dropped to 10-50% of their prospective yield (Quraishi, 2005).

Trees and shrubs of dry regions play a very important role in the enrichment of nutrient poor sandy soil. Their ethno-botanical services are of sustainable significance in view of improving the low nutrient status of the sandy soil (Kellman, 1979; Belsky *et al*., 1989; Bargali and Bargali, 2009). *Capparis decidua* (Forsk.) Edgew (Capparaceae), commonly known as Karir, is a drought tolerant shrub found in arid areas of Pakistan as compact bunches (Gupta, 2010). Along with numerous socioeconomic and environmental benefits (Mahla *et al*., 2010), all parts of the plant have been used in many medicines all over the world. The spicy-tasting fruits serve as an astringent for bowels, a remedy for bad breath and a possible cure for cardiac troubles (Sharma *et al*., 2011). The green young pods are used as anthelminthic and laxatives, and are active in the treating of asthma, constipation, coughs, as well as hysteria and other mental disorders (Ghazanfar, 1994). In many parts of the world, the faded fruit is cooked (Agarwal *et al*., 1988). Green berries are used in manufacturing pickles used as food in some countries (Sharma *et al*., 2011).

The effects of individual trees and shrubs on such soil have been investigated by many scientists in a wide variety of ecosystems. A lot of research work has been done on the ethnobotanical characters of this species. However, little research work regarding the soil plant interaction of *C. decidua* has been done so far. In view of the above discussion, the present study was conducted to find out the role of *C. decidua* in soil enrichment by quantifying differences in soil nutrient status under the plant canopy (UC), at 150 cm away from the canopy (D-150) and 300 cm away from the canopy (D-300).

MATERIALS AND METHODS

The Thal desert covers an area of about 2.5 million hectares and comprises the districts Bhakker, Mianwali, Layyah, Muzzafargarh, Khoshab, Sargodha and Jhang. Annual precipitation of the area is between 150 to 200 mm at 31-33 ^{o} N latitude and 71.07^{o} E at an altitude of 200 meters. The area experiences cold winters and severe, hot summers with temperatures between 0^{o}C to 44^{o}C annually. Soil erosion is experienced in many parts of the Thal desert because of strong winds that blow frequently. The soil is moderately calcareous, with alkaline clay loam and alluvial with a sandy texture (Muhammad, 1989; Quraishi *et al*., 2006). The main vegetation of the Thal range area consists of shrubs and grasses rather than trees. Common shrubs of this desert are *Capparis decidua* (Karir), *Acacia jacquemontii* (Babble acacia), *Calligonum polygonoides* (Phog), *Capparis aphylla* (Karir), *Haloxylon recurvum* (Lana), *Prosopis cineraria* (Jand), *Solvadora oleoides* (Van), and *Tamarix aphylla* (Farash), (Quraishi *et al*., 2006).

The study was conducted at various range sites of the Thal rangeland, i.e Rakh Chobbara, Rakh Kherewala (Layyah), Rakh Dagarkotli (Bhakker). At each site, 10 large shrubs of *Capparis decidua* were randomly selected and tagged. Soil samples in the cardinal directions of each selected shrub were collected with the help of soil augar. The first soil sample was collected under the shrub canopy beside the stem at a soil depth of 15 and 30 cm. The 2nd and 3rdsoil samples were collected at a distance of 150 cm and 300 cm away from the canopy of the selected shrub at the same soil depth and mixed together to form a composite sample for further chemical analysis. The tagged samples were taken to the soil testing laboratory for soil analysis using the standard protocol outlined by Okalebo *et al*. (2002). Value of various parameters like soil organic matter, moisture contents, Nitrogen (N), Phosphorous (P), Potassium (K), Electrical conductivity (EC), Carbonates (CO_3^{--}), Bicarbonates (HCO_3^{-}), Chlorides (Cl) and soil pH were assessed. The mean values of these parameters under various soil regimes (as mentioned above) were compared for their statistical significance using Fisher's LSD test at a 5% probability level. The correlations between various soil property values were determined using the Pearson's linear correlation coefficient.

RESULTS AND DISCUSSION

Soil Organic Matter (OM%)

Presence of soil organic matter

(OM) is the major indication of soil fertility, as it is the only source of soil nitrogen. According to an estimate, one ton of OM adds about 50 kg of N and 5 kg of P and S each to the soil. According to another estimate, in soil organic matter C:N:P:S = 100:10:1:1. Generally speaking, organic matter carrying 8-12 kg of C also contains 1 kg nitrogen (Allison, 1973). Figure 1 depicts organic matter (%) in the soil of *Capparis decidua* collected from 3 different (randomly selected) sites of the Thal desert in the Punjab Province (Pakistan). Data revealed that the maximum value of OM (1.25%) was found in under canopy (UC) soils, followed by its significant decrease (1.05% and 0.83%) from canopy area to 150 cm (D-150) and 300 cm (D-300) away from the plant canopy. For instance, the higher level of OM in the soils from UC than the soils of D-150 and D-300 showed enhanced fertility levels in UC soils under the canopy of *Capparis decidua* plants. Noureen *et al*. (2008) also found relatively higher levels of OM in the UC soils of *C. polygonoides*. It is obvious from the results that UC soils of *C. polygonoides* had more organic matter and it was gradually decreased while moving away from the canopy (Figure 1).

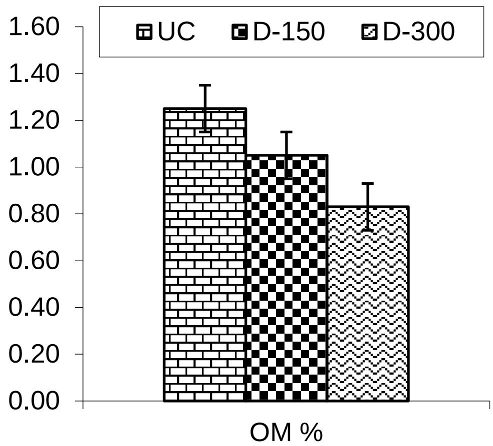

Figure 1: Organic matter concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua.*

Arshad *et al*. (2008) described the same results while working on *Aerva javanica, Dipterygium glaucum, Calligonum polygonoides, Haloxylon salicornicum* and *Capparis decidua*. They reported a significant increase in the OM of the UC soils of the experimental plants than the soils located away from canopy. Data reliability was assessed using statistical indicators such as the coefficient of variance (CV) 0.79%, significance among various means of soil OM (at $p < 0.05$) and the least significant difference (LSD) value (0.17) to compare means with standard error (0.081).

Soil Nitrogen (N%)

Nitrogen (N) is the most claimed inorganic nutrient by plants among all other nutrients. The ratio of N and C in soils usually differ from 10 to 15 times or somewhat greater, and is comparable to that of the **N:P** ratio as declared above (Allison, 1973). The mean nitrogen (N) content recorded in the sampled soil of the experimental area is shown in Figure 2.

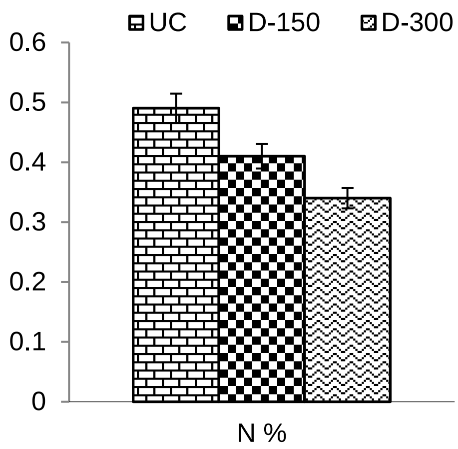

Figure 2: Nitrogen concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua.*

Data revealed that (UC) soils planted with *C. decidua* had higher levels of N as compared to the soils of open area. For instance, higher levels of N (0.49%) was found in UC soils, whereas it significantly decreased in the soils of D-150 (0.41%), followed by D-300 (0.34%). Results proved that *C. decidua* showed higher levels of N in UC soils and the level of N was gradually decreased while moving away from the canopy area. The gradual decrease in N levels, while moving away from the canopy area, clearly suggested that the role of *C. decidua* at the site is synergetic to improve the soil fertility. Noureen *et al*. (2008) stated comparatively greater levels of N in under canopy soils as compared to open areas. Xu *et al*. (2006) studied the canopy effect of *Tamarix ramosissima* in the Oasis desert and revealed that UC soils had higher N contents as compared to open areas. Data reliability is well justified with 1.45% CV and the significance among various means of nitrogen in the soils of experimental sites planted with *C. decidua* at (p < 0.05) could be determined using the LSD value (0.079) and standard error (0.032) for different means, as shown in Table 1.

Table.1: Major statistical indicators for assessing data reliability and level of significance among various means of growth parameters.

Parameters	LSD Value at $p < 0.05$	Standard error	CV %
O.M	0.17	0.081	0.79
N	0.079	0.032	1.45
P	0.049	0.023	4.46
K	0.11	0.052	1.08
S	0.069	0.032	0.79
CO_3^{-2}	0.087	0.041	1.22
HCO_3^-	0.023	0.010	0.79
pH	0.11	0.053	1.05

Soil Phosphorous (P mg/L)

After N, the most limiting available macronutrient for plant growth is P. Phosphorous is of great importance, building up roughly 0.2% of a plant's dry biomass. It is a constituent of basic molecules, such as nucleic acids, phospholipids, and ATP, and, therefore, plants cannot grow without a consistent supply of this mineral nutrient (Theodorou and Plaxton, 1993). It is noteworthy to mention that 20 to 80% of P in soils is present in the organic form, of which phytic acid (inositol hexaphosphate) is generally a main constituent (Richardson, 1994). The rest is present as an inorganic portion comprising about 170 mineral forms of P (Holford, 1997). Obviously, the organic phosphorus compounds are more resistant to biological attacks than are the organic nitrogen and sulfur compounds

Mean phosphorous (P) concentration noted in the soils of various experimental sites is shown in Figure 3.

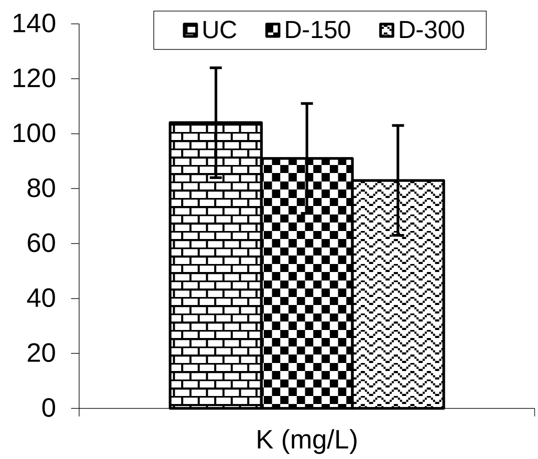

Figure 3: Potassium concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua.*

Data revealed that there was highest phosphorus (P) concentration around the stem base and under the canopy cover of each site which declined linearly towards the open area (away from canopy). The decreasing order of P levels found in the soils of UC vs. soils of D-150 cm and D-300 was: 7.2 mg/L for UC soils > 6.1 mg/L for D-150 soils and 5.3 mg/L for D-300 soils. Karim *et al*. (2009) found higher concentrations of P in under canopy soils as compared to open areas at various sites in the Cholistan desert while working on *Leptadenia pyrotechnica* and *Capparis decidua*. The findings of Kamara and

Haque (1992) and Radaei (2014) are also in agreement with the findings of this study, which explained that the soils of open areas, i.e. away from the base of *C. decidua* plants' influence, is deficient in available P. They stated that P content decreased significantly as the distance from the tree bole increased, getting away from the canopy. Table 1 shows significance among various means of P in *Capparis decidua* with CV (4.46%) at $p < 0.05$ with LSD value (0.049) and standard error (0.023) for different means.

Soil Potassium (K mg/L)

Potassium is the most ample cation in the cells of non-halophytic vascular plants (Maathuis *et al.*, 1997). It is usually the most abundant of the major nutrient elements in soil. The total K content of soils varies from < 0.01% to about 4% and is commonly about 1% (Wild, 1988). Mean contents of K observed in all replicates of the experimental sites is incorporated in Figure 4.

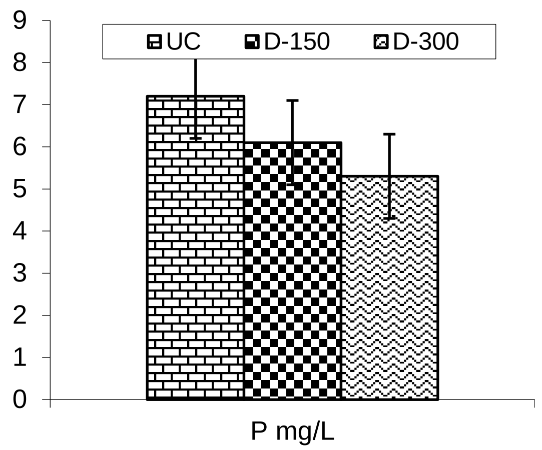

Figure 4: Phosphorous concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua*.

This study showed that under canopy soils had higher contents of K in the above mentioned soils as compared to soils away from canopy. For instance, the decreasing order of K levels found in the soils of UC of the plant vs. D-150 and D-300 was: 104.0 mg/L vs 91 mg/L and 83 mg/L. Githae *et al.* (2011) studied the canopy effect of *Acacia senegal* and found higher K levels under the canopy soils as compared to open area. The reason behind the high concentration of K under the canopy rather than in open areas might be high organic matter accumulation, decomposition and releases in the soil (Brady and Weil, 2002; Holdo and Mack, 2014). Table 1 shows reasonably low CV% (1.08) and standard error (0.052), and recommends that the noted data regarding potassium was highly reliable to interpret the results on a statistical basis at $p < 0.05$ with the LSD value (0.11) for different means.

Soil Sulphur (S mg/L)

Sulphur (S) is an essential element that is required in larger amounts than is generally supposed. Conservative estimates indicate that 50-70% of the sulfur of soils is in the organic matter. Most of the sulfur is present in the organic matter or adsorbed on it. Where the sulfur supply is deficient, plant growth may be markedly retarded (Allison, 1973). The mean contents of S (mg/L) recorded in the experimental soils is shown in Figure 5.

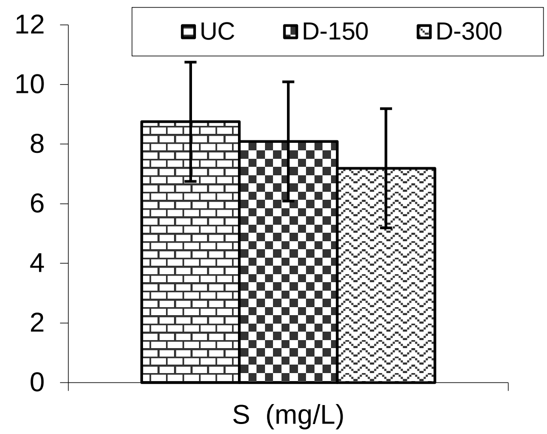

Figure 5: Sulphur concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua*.

Data revealed that the UC soil of *C. decidua* ranked at the top with regard to S concentration in the soil. The same was gradually decreased in the remaining two soils (D150 and D300) while moving away from the plant canopy. The decreasing order of S levels found in UC soils (12.08 mg/L) was > S levels in the soils of D150 (10.42 mg/L) > soils of D300 (8.57 mg/L). Table 1 describes the importance and significance ($p < 0.05$) between several means of S in *C. decidua* at all 4 sites with LSD values of 0.049, CV% of 3.02 and standard error of 0.045 for different means. Blank and Derner (2004) examined the effect of *Lepidium latifolium* on soil properties and perceived high S contents UC as matched to open canopy. Abd El-Fattah and Dahmash (2002) studied the effect of the canopy on soil condition in the North-Eastern Desert of Egypt. They examined the effects of *Alhagi maurorum* (Medio), *Tamarix aphylla* (*Ehrenb) Ege*, *Zygophyllum coccineum* (L), *Halocmmum strobilaceum* (M. Bieb) and also, *Parkinsonia aculata* (L) and found higher levels of Sulphur in under canopy soils of all above mentioned plant species. Similar results were quoted by Jafari *et al*. (2003) while working in Hoz-e-Soltan of Qom province, Iran, on the soil-Plant relationship. They described higher levels of Sulphur in under canopy soils.

Level of Carbonates (CO_3^{--} meq/L)

The Carbonates present in soil can disturb soil production by manipulating soil pH, structure, water holding capacity and H_2O movement. They can alter soil structure by modifying the texture and amending the aggregation of soil particles (McCauley *et al*., 2005). The critical C:S ratio in carbonaceous materials above which immobilization occurs rather than mineralization has been reported to be approximately 50: 1 (C:N ratio = 5), but this ratio will vary widely depending on the nature of the carbon source (Allison, 1973). The mean CO_3^{--} concentration recorded in the soils of experimental sites is shown in Figure 6.

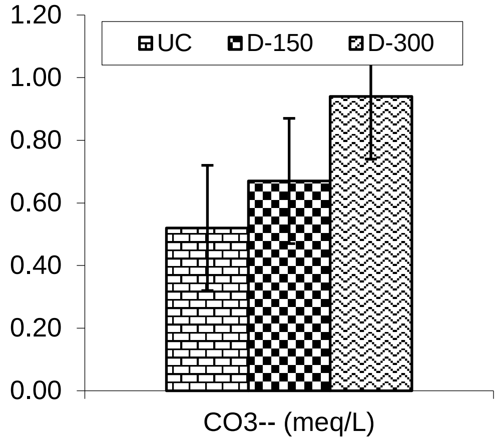

Figure 6: Carbonate concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua*.

Highest concentrations (0.94 meq/L) of CO_3^{--} were recorded in the soils of D-300, i.e. 300 cm away from the plant canopy, which markedly declined in the soil of D-150 (0.67 meq/L) and in UC soils (0.52 meq/L). The increasing order of CO_3^{--} levels found in the soils of UC to open area soils was: CO_3^{--} in UC soils (0.52 meq/L) < CO_3^{--} in the soils of D-150 (0.67 meq/L) < CO_3^{--} in the soils of D-300 (0.94 meq/L). It is desirable for plant growth to have relatively smaller amount of soil CO_3^{--}in the soil because higher concentrations of soluble carbonate may reduce the soil permeability in the upper 50 cm layer of soil (Peverill *et al*., 1999; Maleki *et al*., 2014). Chahouki *et al*. (2008) described the same results of CO_3^{--} while studying the soil-plant association in the Poshtkou range area of Yazd province Iran.

Table 1 showed the reliable value of CV% (1.22%) with standard error (0.041) for the data analyzed for soil carbonate at $p < 0.05$. According to the data analyzed, the significance among means for soil carbonate as influenced by the canopy cover of *Capparis decidua* was determined using LSD value of (0.087).

Level of Bicarbonates (HCO_3^- meq/L)

HCO_3^- is an essential component involved in plant growth on calcareous soils (Woolhouse, 1966a). Its existence in a larger quantity has adverse effects on the preoccupation of ions and results in chlorosis in plants (Brown, 1961). High levels of HCO_3^- in soils and water appear to prevent the metabolic development of vegetation, which eventually disturbs the vegetal development and the endorsement of nutrient minerals (Dogar *et al*., 1980).

The mean HCO_3^- concentration recorded in the soils of all experimental sites is shown in Figure 7.

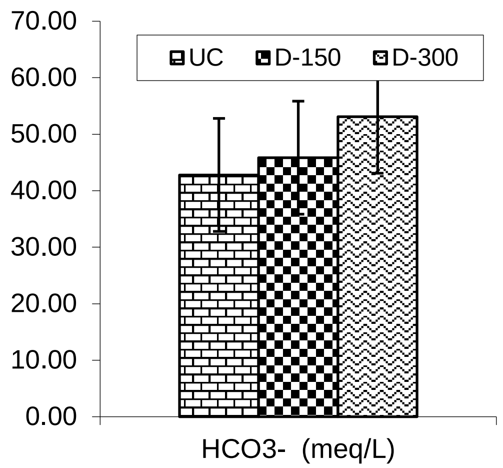

Figure 7: Bicarbonate concentration in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua*

Trends of HCO_3^- concentrations at all sites were: UC soils > D-300 > D-150 away from canopy cover soils. The decreasing order of HCO_3^- levels found in the soils of UC vs. D-150 and D-300 at various experimental sites was: 42.80 meq/L (UC soils) > 45.85 meq/L (D-300 soils) > 53.10 meq/L (D-150 soils). Noureen *et al*, (2008) also found relatively, higher levels of HCO_3^- in the soils away from the canopy as compared to under canopy soils. Relatively less CV% (0.79) with a standard error (0.01) and LSD (0.023) explored that data regarding HCO_3^- levels in the field for different means as influenced by the canopy cover of *Capparis decidua* was reliable at $p < 0.05$.

Soil pH

The mean pH of the soil collected from 4 sites is given in Figure 8. Highest pH values were recorded in open areas, i.e. at 300 cm and 150 cm away from canopy cover in all above mentioned sites, as compared to under the canopy.

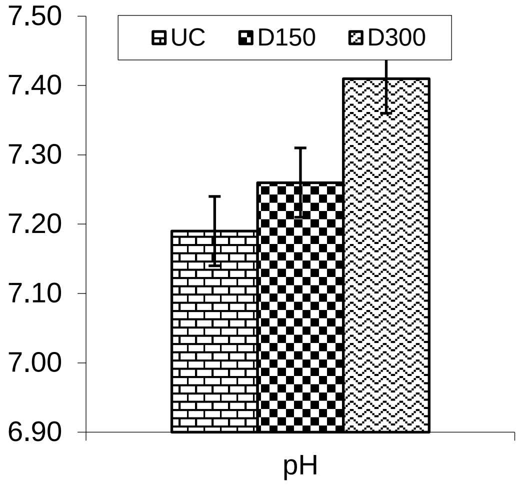

Figure 8: pH in soil under the canopy, at 150 and 300 cm away from canopy of *Capparis decidua*.

The decreasing order of pH levels found in the soils D-300 vs. D-150 and UC soils at various sites was: pH of D-300 soils (7.41) > pH of D-150 soils (7.26) > pH (7.19) of UC soils. Analysis of variance yielding CV% (1.05) with a standard error of (0.053) and LSD value of (0.11) for different means showed data reliability concerning soil pH as influenced by the canopy cover of *Capparis decidua*. Leonard and Field (2003) in Australia compared the canopy effect of *Acacia faliciformis* (Mountain Hickory) and *Eucalyptus mannifera* ssp maculosa (Brittle Gum) on soil fertility and noted relatively low soil pH under the plant canopy in both cases. However, the under canopy soil of *Acacia faliciformis* showed significantly lower pH as compared to the under canopy soil of *Eucalyptus mannifera*.

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