Effect of Various Agroforestry Tree Species on Soil Chemical Properties of Irrigated Tree Plantation of Pakistan

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Abstract

Pakistan is a forest deficient country and natural forests are seriously depleted due to overutilization and lack of proper conservation practices. Agroforestry is being promoted to release the pressure on the natural forests as well as to increase farmlands utility and production. Selecting tree species with the potential to increase soil fertility and offers less competition to the main crops is a fundamental problem. Two exotic species *Acacia nilotica*, *Eucalyptus camaldulensis,* and an indigenous species, *Dalbergia sissoo* were used to understand their role in changing the soil composition under an irrigated plantation environment. Their effect was studied both at different soil layers and under and away from the canopy. All three species significantly affected the chemical composition of the soil. Results revealed that the electrical conductivity, organic matter, N, P, K, and soil moisture were significantly higher under the canopy as compared to away from the canopy. Most of the activity and significantly high minerals were found at 15–30 cm as compared to 0–15 cm soil strata. *Dalbergia sissoo* is a deciduous tree and produced more leaf litter outperformed *A. nilotica* and *E. camaldulensis. E. camaldulensis* suppressed the understory growth of other plant species thus threatening local flora and fauna therefore should not be recommended for plantation on farmlands. *D. sissoo* a shade-intolerant shall be planted alone or mix with *A. nilotica* would be a preferred choice as they complement well due to sparse canopy of the latter. *D. sissoo* is mainly used for timber wood production whereas *A. nilotica* is used for fuelwood will help cope with the wood supply chain. It is therefore concluded that planting tree species improve the soil conditions positively however selection of the tree species should be done with caution. Agroforestry has the potential to reduce the gap existing in timber wood production in Pakistan.

Keywords: Dalbergia sissoo, Acacia nilotica, Eucalptyus camaldulensis, soil fertility, agroforestry

1. Introduction

Soil is the composite façade of physical, chemical, and biological processes which take place across spatial and temporal scales (Robertson and Gross, 1994). Determinants of soil conditions in nature are parent material and typical weather (Birkeland, 1984). In nature, forests are the most prolific bionetwork. For instance, soil fertility changes can be induced by tree species through the decomposition process which is influenced by microclimate and microbial communities in the forest floor (Hobbie 1996; Sariyildiz and Anderson, 2003; Mitchell et al., 2007). Trees play a critical role in biogeochemical recycling (Kelly et al. 1998). Soil fertility in forested areas is improved mainly by adding plant litter. Soil fertility under the tree cover is improved, which decreases soil erosion, adds soil organic matter, provides nutrients through effective litter recycling. Due to urbanization, industrialization and population pressure on agricultural lands has increased many folds. These factors did not affect only environmental conditions but also affect agricultural production. Soil fertility can be maintained by the tree litter during the decomposition process, provides organic matter and nutrients (Koukoura et al. 2003). Information's regarding soil-plant interaction is an integral means to maintain

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the sustainability of a productive system (Koukoura et al. 2003). Pakistan is a forest deficient country and natural forests have depleted at an alarming rate mainly due to overutilization and climate change. The agroforestry system is being promoted to release pressure on natural forests and conserve them. It is however extremely important that appropriate tree species are selected which not only produce useful biomass but also increase farmland fertility. This study was therefore conducted to determine the effect of three selected tree species i.e. *Acacia nilotica*, *Eucalyptus camaldulensis* exotic species, and *Dalbergia sissoo* a native species, planted in an irrigated plantation, on the soil chemical composition.

2. Materials and Methods

This research was carried out in Chichawatni Reserved Forest located in Punjab Pakistan. Chichawatni Reserved Forest is situated in District Sahiwal along with Lahore – Karachi Railway Line between Kassowal and Dad Fatiana Railway Stations Punjab Pakistan. The plantation is located in southern zone Punjab Pakistan between latitudes 30^{o}-29´-32.91´´N and 30^{o}-33´-45.84´´N and longitudes 72^{o}-36´-00.25´´E and 72^{o}-46´-48.65´´E at an elevation of 153.6 to 163.7m above sea level. The plantation is almost linear in form. It has a total area of 11531 acres. The parent material of the plantation consists of loamy soil. The local climate is generally hot often gets extremely hot during summers with mild winters. May, June, and July are the hottest months of the year when the temperatures soar to 40-50°C. While winter temperature ranges between 5-10°C. The average rainfall is 200 mm annually. Chichawatni Irrigated Plantation originally was a typical dry tropical forest. The indigenous flora was dominated mainly by *Salvadora oleoides*, *Tamarix articulate*, *Prosopis cineraria*, and *Capparisa phylla*. Recently other species such as *Acacia nilotica*, *Eucalyptus camaldulensis*, and *Dalbergia sissoo* are also planted due to their fast growth and economic importance in the timber wood and fuelwood industry.

Figure 1. Map of Chichawatni plantation, located in Chichawatni Punjab, Pakistan.

2.1 Collection of Soil Samples

Soil samples were collected from under and away from the canopies of *A. nilotica*, *D. sissoo*, and *E. camaldulensis*. In the case of away canopy, soil samples were taken at a distance of 300 cm from the tree canopy at two different soil depths i.e. 0-15 cm and 15-30 cm with the help of a soil augar. Soil samples were collected in cardinal directions and a composite sample was made by randomly taking four samples from each tree species to make one sample. Five composite samples for each species were analyzed for soil organic matter, moisture content, nitrogen (N), phosphorous (P), potassium (K), sodium (Na), fsulfur (S), chloride (Cl), carbonate (Car), bicarbonate (Bicarb), electrical conductivity (EC), soil pH and soil moisture (SM) respectively. Soil analysis was carried out by using standard protocols outlined by Okalebo et al., (2002). Analysis of variance (ANOVA) was used to understand the effects of different tree species on soil chemistry. Duncan Multiple Range Test (DMRT) was carried for mean comparison by using the "*agricolae*" package incorporated in the R environment (R Core Team 2013). Pearson's correlation coefficient and biplot analysis erewere conducted to understand the association between different soil components.

3. Results

The results indicated that three tree species had variable effects on the soil composition and it varied by the depth of the soil layer (Table 1). The data were expressed as the mean for soil depth, sampling site, and type of species.

3.1 Soil pH

Soil pH was significantly different at soil depth but a distance from canopy and species did not affect it significantly. Soil pH was higher at 15 – 30 cm as compared to 0 – 15 cm. The pH of the soil was higher under the canopy of *E. camaldulensis* (Table 1) however this difference was not significant.

3.2 Soil electrical conductivity (EC)

Soil EC was significantly affected by soil depth and distance from canopy however all tree species did not show any difference in EC (Table 1). Soil EC measured under the canopy of the plantation was significantly higher than that away from the canopy. In 0 -15 cm soil depth EC was significantly higher than in 15-30 cm depth.

3.3 Organic matter (OM)

Total organic carbon is significantly affected by soil depth, distance from the canopy, and type of species (Table 1). The concentrations of the organic matter recorded in *A. nilotica*, *D. sissoo,* and *E. camaldulensis* soils were 1.226, 1.125, and 1.085% respectively (Table 1). The values of organic matter under *D. sissoo* were significantly higher than under *A. nilotica* and *E. camaldulensis*. A significant difference in organic matter was also observed between under and away from canopies of tree plantation and was higher under the canopy than that away from the canopy. Depth effect was also significant and organic matter was high in 15-30 cm soil depth than that in 0-15 cm depth.

3.4 Total Soil Nitrogen (N)

The results showed that total soil N was significantly affected by soil depth, distance from the canopy, and type of species (Table 1). Significantly higher soil N concentration was observed under *E. camaldulensis* than that under *A. nilotica* and *D. sissoo*. Values of soil N were significantly higher under the canopy of tree plantation in 0-15 cm depth than those away from a tree canopy in 15-30 cm depth. Total nitrogen decreased by depth but increased under the tree canopy.

3.5 Available Phosphorus (P)

Soil depth, canopy distance, and type of species used had a significant effect on the available phosphorus (Table 1). Generally, high phosphorus was available under the canopy and at the deeper layer for both *E. camaldulensis*, *A. nilotica*, and less for *D. sissoo*. Higher phosphorus at a depth of 0-15 cm was found under the canopy of *E. camaldulensis* and a minimum was observed under the canopy of *D. sissoo*. At 300 cm away from canopies of these tree species at the same depth significantly higher value was observed for *A. nilotica* and the lowest value was observed for *D. sissoo*. At 15-30 cm depth the maximum phosphorus was obtained for *E. camaldulensis* while minimum value was found for *D. sissoo*.

3.6 Available Potassium (K)

Total potassium is significantly affected by soil depth, distance from the canopy, and species type (Table 1). The mean soil K concentration was significantly higher in *E. camaldulensis* and the lowest was observed for *D. sissoo*. Significantly higher soil K concentration was observed under the canopy of tree plantation than that away from the canopy. Likewise, 15-30 cm soil depth showed significantly higher soil K concentration as compared with that in 0-15 cm depth.

3.7 Available Sodium (Na)

Total sodium (Na) was significantly different for soil depth and distance from canopy however species did not aaffect sodium contents significantly (Table 1). Sodium concentration was high away from the canopy and in a deeper soil layer as compared to away from the canopy and top layer of the soil. The type of species did not affect sodium concentration significantly.

3.8 Sulphur (S) and Chloride (Cl)

Soil depth had a significant effect on S and Cl concentrations and distance from canopy species type did not affect them significantly (Table 1). Both were found to be in higher concentration at the deeper layer of soil as compared to the upper layer of soil for S and Cl concentration in soils of *A. nilotica, D. sissoo,* and *E. camaldulensis*. Soil S was higher in *A. nilotica* soil while Cl was higher in *E. camaldulensis* soil. The soil under canopies of tree plantation showed comparatively higher soil S and Cl concentrations than those away from the canopy. Soil S and Cl varied significantly in 0-15 and 15-30 cm soil depths and significantly higher concentrations of both S and Cl were recorded in 15-30 cm soil depth.

3.9 Carbonates (Carb) and Bicarbonates (Bicarb)

Soil carbonates were significantly affected by soil depth and distance from the canopy (Table 1). They were not affected by different tree species. Similarly, a high concentration of bicarbonates was observed in the deeper layer of soil and it was affected by distance from canopy and type of species respectively. All species had a similar contribution of carbonates and bicarbonates in the soil.

3.10 Soil Moisture Content

Moisture content determined in the soil under the canopy and at 300 cm away at two depths (0-15 cm and 15-30 cm) from the canopy of *D. sissoo, A. nilotica,* and *E. camaldulensis* in the Chichawatni Forest plantation is presented in Table 1. Moisture contents were significantly affected by distance from the canopy. Under canopy had more moisture than away from the canopy. Soil depth and tree species did not affect moisture contents significantly. *E. camaldulensis* had lower soil moisture followed by *A. nilotica* and *D. sissoo* respectively.

3.11 Association among soil properties of tree plantation

The PC1 and PC2 of PCA explained 55.2% of the total variability (Fig.1). Associations among soil chemical properties of tree plantation under and away from canopies of *D. sissoo, E. camaldulensis,* and *A. nilotica* were explored with the angles between vectors. The angle between two vectors indicates a correlation between soil chemical components (Table 2), obtuse and acute angles indicate a negative and positive association, respectively. The biplot showed that EC, pH, K, SM, N, and P were oriented toward the same plain these traits were positively correlated with each other as well as with root. The vectors of carbonates, Na, Cl, bicarbonates, S, and OM were also oriented in the same direction in another plain showing positive correlations among these properties. Table 2 shows that soil pH was significantly and positively correlated with soil EC, OM, P, S, and bicarbonates. Soil OM also showed a significant positive correlation with soil EC, N, S, and bicarbonates. Soil Na and P showed a significant negative correlation with each other. As shown in Figure 1., most soil parameters showed positive correlations among themselves, but fewer showed negative correlations, but these were not significant.

4. Discussion

Woody plants have the potential to improve soil quality in different ways. Soil physical, chemical, and biological quality areare greatly improved by tree species because of the addition of large amounts of leaf, root, twig, flowers, and fruits biomass to the soil (Sarvade et al., 2019). Overall, tree species affected the soil's chemical properties. Changes in soil chemical properties under various tree species have been widely reported (Russel et al., 2007; Phillips and Fahey, 2008). Differences in soil chemical properties among tree species might be due to release of organic acids, quality or quantity of litter accumulated and the litter decomposition rate, and nutrients uptake or movement of nutrients from deeper soil to surface soil layers (Jobbágy and Jackson, 2004; Russel et al., 2007). Environmental conditions and the type of tree species also contribute to the variations in the soil's chemical properties (Ayres, 2009). Soil pH is a good indicator of soil microbial biomass and activity and plays an important role in the mineralization and availability of nitrogen (Tian et al., 2013). In our study tree species did not show a significant change in soil pH, EC, Na, S, Cl, Carb, Bicarb, and SM. They however significantly affected OM, N, P, and K respectively. *D. sissoo* showed high EC, OM, Carb, and SM contents. Soil moisture is also significantly and positively correlated with OM and EC. However, pH was comparatively low in *D. sissoo* soil and the highest was in *E. camaldulensis*. *D. sissoo* is deciduous species with a bigger canopy thus will have more litterfall as compared to *A. nilotica* and *E. camaldulensis D. sissoo* is mainly a subtropical species that vehave a low tolerance for salinity as compared to high tolerant *E. camaldulensis* with a very high salinity tolerance. *E. camaldulensis* is also notorious for allelopathic eeffects thus has the potential to change soil pH and high salt tolerance. Marked suppression of vegetation was also observed under its canopy thus creating a major threat for local flora and fauna, reduced soil fertility, and increased soil erosion. Lower pH may thus be attributed to increased accumulation of aboveground biomass, cation uptake, and synthesis of organic acids by different tree components (Sarvade et al., 2014). EC was significantly affected by the distance from the canopy and soil depth. EC was high under the canopy due to the high accumulation of tree litter and on the upper soil strata. High EC was reported for the soil under *Acacia senegal* as compared to open areas (Githae *et al.*, 2011). EC is significantly related to moisture content and other available minerals in the soil. This was particularly observed in *D. sissoo* where indigenous soils had low EC (<1.0) as compared to newly established areas (>1.0) in Pakistan (Asif et al., 2019). Changes in EC of soil reflect drought conditions in a particular area which predisposes tree species to different pathogens. *D. sissoo* is particularly sensitive to high saline conditions as it is a subtropical species that require a high amount of freshwater. The relatively lower organic matter in *E, camaldulensis* soil is possibly due to the differences in the rates of plant litter decomposition under the *A. nilotica* and *D. sissoo* plantation (Demessie et al., 2012). According to Sharmsher et al. (2002), low organic matter (<1%) was found in 83% of the soil samples in *E. camaldulensis* plantation areas. Species showed highly significant differences for N, P, and K. Interestingly *E. camaldulensis* and *A. nilotica* showed the highest NPK constituents followed by *D. sissoo* despite low leaf litter mass deposited. *D. sissoo* can utilize more K due to intermediary absorption by mycorrhizae as compared to other species. Nitrogen concentration in soils is reflected in part by the rate of decomposition of the plant material (Cao et al., 2010). Low concentrations of nutrients are released due to slow decomposition of eucalypt that contains litter with low nutrient concentration (Aweto and Mokele, 2005; Baber et al., 2006; Cao et al., 2010; Demessie et al., 2012) and coupled with the prevailing low soil pH, N mineralization from the *E. camaldulensis* litter would have been considerably slow. Additionally, high soil nutrient uptake rates of the plant under eucalypts exhibited the total available N (Tererai et al., 2014). Similarly, phosphorus becomes inaccessible for plant use due to higher immobilization by eucalypts (Aweto and Mokele, 2005). In our study contrasting results of soil, phosphorus aswas observed as the soil P content was in sufficient range in *E. camaldulensis* soil. The addition of organic matter and reduction in soil moisture losses help to conserve soil moisture due to improved soil structure in tree-based systems. Soil moisture concentration in each profile depth improves due to an increase in organic matter, reduction in evaporation, and erosion by the perennial tree species from natural forest and agroforestry systems (Saha et al., 2004). The soil organic carbon is the key factor of improved soil properties (Akhtar et al., 2018). The results of our study revealed that *D. sissoo* showed significantly higher organic carbon contents. EC, OM, N, P, K, Na, Carb, and SM were significantly higher under tree canopy as compared to away from the canopy. This could be due to the accumulation and slow rate of decomposition of leaf litter under the canopy. Similarly, most of the soil activity was observed between 15-30 cm soil layer as it is reflected with relatively high pH, OM, P, K, Na, S, Cl, Carb, bicarb, and SM respectively. Noureen (2007) reported similar results on under canopy of *Calligonum polygonoides* and *Acacia jacquemontii* at 150 cm and 300 cm soil depth in the Cholistan desert. Similarly, Karim *et al.* (2009) found a high percentage of moisture and other mineral contents under canopy soil as compared to an open area, while working on *Leptadenia pyrotechnica* and *Capparis decidua.* A high amount of available nitrogen (1.01-1.25 times) was observed as compared to an open area (0.83-0.94 times) due to the high rate of leaf shedding and root decay (Cusak et al., 2009). *D. sissoo* and *A. nilotica* are leguminous crops preferred for agroforestry due to their positive effect on soil fertility and productivity. An increased N and S concentrations were reported in other leguminous tree species of tropical savanna (Abule et al., 2007, Ceck et al., 2008). A high concentration of phosphorous under the canopy was also reported in the sites of low soil fertility and rainfall due to the enrichment of soil by woody plants (Tredyte et al., 2007). Potassium is the most abundant cation in the cells of non - halophytic higher plants (Maathuis et al., 1997). It is usually the most abundant of the major nutrient elements in the soil. The total K content of soils varies from <0.01% to about 4% and is commonly about 1% (Wild, 1988). Similar results were also quoted by Imoro et al. (2014) while studying soil-plant improvement as influenced by planting *Voandzeia subterranean* and *Arachis hypogea*. Arshad et al., (2008) described the higher contents of potassium under the canopy of *Aerva javanica*, *Dipterygium glaucum*, *Calligonum polygonoides*, *Haloxylon salicornicum,* and *Capparis decidua*. Carbonates were mainly affected by distance from the canopy and soil depth. Chahouki *et al.* (2008) found high carbonate concentration away from the canopy as compared to other mineral contents that were higher in under the canopy soils in Poshtkou rangelands of Yazd province Iran.

The PCA showed that soil organic carbon was positively correlated with nitrogen, phosphorus, potassium, and sulfur (Figure 1). A major feature of soil organic matter is that it holds a relatively constant ratio of the different nutrients (Kirkby et al., 2011). In the decomposition of the soil organic matter, these nutrients can be released into the soil although how much becomes available to plants depends on a range of factors. In the formation and then in the decomposition of soil organic matter, a flux of nutrients or recycling of nutrients is an outcome. Phosphorus occurs in several pools in the soil and in many soils, the P from soil organic matter may be only one of these pools (Shen et al., 2011). The mineralization of plants and soil organic matter can be a major source of P for plants (McLaughlin, 2011).

5. Conclusion

Agroforestry is aggressively promoted in Pakistan to conserve natural forests as they are depleting at an alarming rate and to cope with market demand for timber wood and fuelwood. Different tree species have variable effects on the soil properties directly or indirectly therefore it is important to select tree species with increased biomass as well as which enhance the productivity of the farm soils. Agroforestry tree plantation can be a good option for improving soil chemical properties and for achieving the sustainable use of soil. Not only does soil improvement benefit soil and water conservation to avoid erosion losses but also helps to increase the productive capacity of the soil through improving soil chemical properties. This study aimed at assessing the effect of *Acacia nilotica*, *Eucalyptus camaldulensis* exotic species, and *Dalbergia sissoo* an indigenous species on the soil chemistry. It was observed that trees have changed the chemical properties of the soils sampled under the selected tree stands. They had a similar effect on soil pH, EC, Na, S, Cl, Carb, Bicarb, and moisture contents. Generally, *D. sissoo* and *A. nilotica* had improved soil chemistry as compared to *E. camaldulensis*. It was generally observed that *E. camaldulensis* suppressed understory growth of other plants resulting in low litter intensity and soil erosion. *D. sissoo* and *A. nilotica* are legumes and they have the potential to be established in the local agroforestry system due to their potential of increasing soil properties. Moreover improved soil properties by some tree species could be associated with the nutrient uptake from the subsurface zones, recycling, biological nitrogen fixation, and solubilizing plant nutrients. Therefore it is recommended that *D. sissoo* and *A. nilotica* shall be preferred over *E. camaldulensis* for agroforestry sectors. This is particularly important in a mixed planting scheme as *E. camaldulensis* suppresses understory vegetation and also due to its high water requirement as compared to other two speices. *D. sissoo* is shade intolerant thus shall be planted in a pure tree stand or mix with *A. nilotica* having sparse canopy and less shade effect on *D. sissoo*.

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Table 1: Summary of soil chemical parameters analysed for different tree species.

	F- Value	Distance	Depth	Species
pH	Distance=3.692 N-S Depth=10.256** Species=0.179 N-S	Away =8.04±0.098 Under=8.11±0.113	15-30 (cm)=8.133±0.081 (a) 0 -15 (cm)=8.022±0.108 (b)	*Acacia nilotica*=8.075±0.113 *Dalbergia sissoo*=8.067±0.115 *Euclayptus camaldulensis*= 8.092±0.108
EC	Distance=5.67* Depth=32..07** Species=1.54 N-S	Away =1.789±0.273 (b) Under=1.975±0.378 (a)	15-30 (cm)=1.661±0.257 (b) 0-15 (cm)=2.104 ±0.256 (a)	*Acacia nilotica*=1.798±0.382 *Dalbergia sissoo*=1.967±0.231 *Euclayptus camaldulensis*=1.882±0.386
OM	Distance =19.78** Depth=75.89** Species=9.38**	Away =1.084 ± 0.126 (b) Under= 1.206 ± 0.194 (a)	15-30 (cm)=1.264±0.141 (a) 0-15 (cm)=1.026±0.108 (b)	*Dalbergia sissoo*=1.226±0.128(a) *Acacia nilotica*=1.125±0.169(b) *Euclayptus camaldulensis*=1.085±0.195 (b)
N	Distance=38.722*** Depth=6.63* Species=3.978*	Away =0.650±0.097 (b) Under=0.779±0.079 (a)	15-30 (cm)=0.688 ±0.089 (b) 0-15 (cm)=0.742 ±0.123 (a)	*Acacia nilotica*=0.721 ±0.106(a) *Dalbergia sissoo*=0.677±0.128(a) *Euclayptus camaldulensis*=0.748±0.085 (b)
P	Distance=57.12** Depth=8.88** Species=14.46**	Away =5.67±0.878 (b) Under=7.25±0.878 (a)	15-30 (cm)=6.77±1.14 (a) 0-15 (cm)=6.15±1.16 (b)	*Euclayptus camaldulensis*=6.95±1.10(a) *Acacia nilotica*=6.76±0.961 (a) *Dalbergia sissoo*=5.68±1.12(b)
K	Distance=6.49* Depth=22.44** Species=6.41**	Away =126.11±20.02 (b) Under=138.06±18.49 (a)	15-30 (cm)=143.06±14.69 (a) 0-15 (cm)=121.11±18.63 (b)	*Euclayptus camaldulensis*=140.6±14.13 (a) *Acacia nilotica*=134.8±18.07(a) *Dalbergia sissoo*=120.08±22.65(b)
Na	Distance=15.26** Depth=5.957* Species=0.179N-S	Away =1.12±0.322 (a) Under=0.708±0.294 (b)	15-30 (cm)=1.043±0.337 (a) 0-15 (cm)=0.786±0.362 (b)	*Acacia nilotica*=0.942±0.403 *Dalbergia sissoo*=0.922±0.261 *Euclayptus camaldulensis*=0.879±0.445
S	Distance=1.812N-S Depth=12.885** Species=0.002 N-S	Away =6.539±0.917 Under=6.939±0.94	15-30 (cm)=7.272±0.893 (a) 0-15 (cm)=6.205±0.645 (b)	*Acacia nilotica*=6.75±0.987 *Dalbergia sissoo*=6.73±0.978 *Euclayptus camaldulensis*=6.74±0.935
Cl	Distance =0.946N-S Depth=34.064** Species=0.066N-S	Away =1.903±0.862 Under=1.731±0.525	15-30 (cm)=2.33±0.516 (a) 0-15 (cm)=1.30±0.452 (b)	*Acacia nilotica*=1.783±0.753 *Dalbergia sissoo*=1.801± 0.727 *Euclayptus camaldulensis*=1.860±0.709
Carb	Distance=93.04** Depth=41.044** Species=0.086N-S	Away =0.458±0.112 (a) Under=0.233±0.082 (b)	15-30 (cm)=0.421±0.143 (a) 0-15 (cm)=0.271±0.119 (b)	*Acacia nilotica*=0.342±0.169 *Dalbergia sissoo*=0.353±0.143 *Euclayptus camaldulensis* = 0.343±0.149
Bicarb	Distance=2.20N-S Depth=13.75** Species=0.038N-S	Away =2.217±0.805 Under=2.214±0.699	15-30 (cm)=2.83±0.407 (a) 0 -15 (cm)=1.59±0.401 (b)	*Acacia nilotica*=2.28±0.730 *Dalbergia sissoo*=2.21±0.770 *Euclayptus camaldulensis* = 2.16±0.788
SM	Distance=6.774* Depth=2.445N-S Species=0.626N-S	Away =5.77±0.529 (b) Under=6.30±0.632 (a)	15-30 (cm)=6.194±0.631 0-15 (cm)=5.877±0.613	*Acacia nilotica*=5.944±0.466 *Dalbergia sissoo*=6.195±0.604 *Euclayptus camaldulensis*=5.967±0.809

Table 2: Association and effect of tree species, soil depth and distance from canopy on various soil chemical components in an irrigated plantation.

	pH	**EC**	**OM**	**N**	**P**	**K**	**Na**	**S**	**Cl**	**Carb**	**Bicarb**	**SM**
pH	1	0.45**	0.58**	0.28	0.51**	0.54**	0.03	0.6**	0.17	0	0.41**	0.16
EC	0.45**	1	0.70**	0.23	0.29	0.43**	0.12	0.61**	0.46**	0.05	0.56**	0.36*
OM	0.58**	0.70**	1	0.36	0.28	0.35	0.03	0.5**	0.27	0.03	0.5**	0.41**
N	0.28	0.23	0.36	1	0.63**	0.37	-0.25	0.34**	0.05	-0.34*	0.22	0.28
P	0.51**	0.29	0.28	0.63**	1	0.62**	-0.39*	0.42**	0.04	-0.37*	0.2	0.21
K	0.54**	0.43**	0.35	0.37	0.62**	1	-0.02	0.46**	0.34*	0.07	0.45*	0.05
Na	0.03	0.12	0.03	-0.25	-0.39*	-0.02	1	0.09	0.4**	0.64**	0.32	0.01
S	0.6**	0.61**	0.5**	0.34**	0.42**	0.46**	0.09	1	0.38*	0.1	0.72**	0.02
Cl	0.17	0.46**	0.27	0.05	0.04	0.34*	0.4**	0.38*	1	0.51**	0.76**	0.12
Carb	0	0.05	0.03	-0.34*	-0.37*	0.07	0.64**	0.1	0.51**	1	0.36*	-0.18
Bicarb	0.41**	0.56**	0.5**	0.22	0.2	0.45*	0.32	0.72**	0.76**	0.36*	1	0.03
SM	0.16	0.36*	0.41**	0.28	0.21	0.05	0.01	0.02	0.12	-0.18	0.03	1

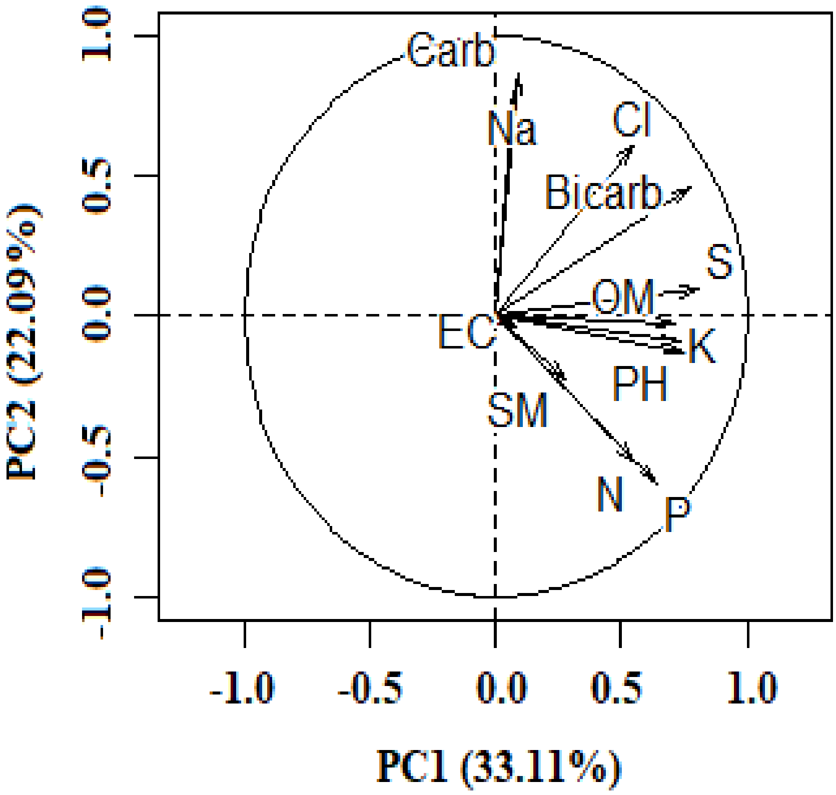

Figure 2. Biplot showing association between different soil chemical components sampled at different soil depths, under and away canopy of three tree species.