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Comparative effect of *Acacia modesta* and *Olea ferruginea* trees on soil characteristics of Dharabi watershed, Chakwal, Pakistan

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Abstract

Soil nutrient availability and physio-chemical properties under *Acacia modesta* and *Olea ferruginea* trees growing in rangeland and agricultural land were compared at Dharabi Watershed, Chakwal, Pakistan. Change in soil characteristics under these tree species were recorded at a depth of 0-15 cm, 16-30 cm, and 31-45 cm and at various distances (1, 3, and 5 m) from tree trunk. Available P, K and saturation percentage were found higher under *Olea ferruginea* as compared to *Acacia modesta*. Results showed that soil of rangeland under *Olea ferruginea* had moderately higher N (0.25 mg/kg), P (6.36 mg/kg), pH (7.83), EC (0.339 dS/m), total organic carbon (2.83 g/kg), $CaCO_3$ (23.60 mg/kg), organic matter (0.49%) and bulk density (1.55 g/cm^3). It was concluded that *Olea ferruginea* had positive impact on soil physio-chemical properties through improving OM and EC and macronutrients availability. Therefore, this tree species can be suggested as a suitable alternative for sustainable plantation in Dharabi watershed area.

Keywords: Macronutrients, Physio-chemical properties, Soil, Tree species

Introduction

In forest ecosystem, trees are dominant factor with vast effect over chemical, physical and biological characteristics of the soil. Different tree species had significant effects on water balance and microclimate. The physical characteristics of soils are significantly altered depending upon over-story species and modifications of the soil fauna (Frouz *et al*., 2013; Kaushal *et al.,* 2016). The rates of organic matter mineralization and nitrification seem to be dependent on tree species (Augusto *et al*., 2002). Improvement in soil characteristics through higher silt and clay composition has been associated with different tree species as compared to bare soils (Dutta and Agrawal, 2002). Significant effect of trees has been observed on soil biota and decomposer communities which are promoted by litter produced by roots (Vivanco and Austin, 2008). In addition to biomechanical effects of trees on soil, retention of biogenic elements i.e. C, N and P has been considered important aspect of understanding biogeochemical and water cycle system in ecology (Brady and Weil, 2008). The soil properties, site factors and seasonal variations have direct effect on the performance of tree species (Mathur, 2016; Katoch *et al.,* 2017). Trees play positive role in improving soil chemistry and structure through root growth by forming soil pores and aggregates, producing litter and root exudates which increase carbon by adding organic matter into soil (Brady and Weil, 2008). Trees are beneficial for physical displacement of soil by root growth and infilling of stump rot pits (Phillips and Marion, 2006). Bargali *et al*. (2009) reported effects of crown diameter and height of tree on growth of crops. Impact of trees on various crops is age dependent along with the differences in physio-chemical differences in top soils and forest floors developed under diverse species (Augusto *et al*., 2002).

It is imperative to evaluate role of trees in soil carbon storage as trees are particularly important for carbon cycling and their potential to mitigate the effects of climate change globally (Lal, 2004). The soil-tree interaction helps environmentalists to understand the phenomena of how species traits affect immediate surrounding and its subsequent impact on biodiversity and ecological functioning (Schimel *et al*., 1994). Selection of plant species for agro-silvo-pastoral or ecological reclamation programs must be based on a deeper knowledge of the existing relationships between plant species and soil nutrient dynamics in each ecosystem (Galicia *et al*., 2008). Hagen-Thorn *et al*. (2004) studied effect of six European tree species on the chemical properties of mineral top soils in forest plantations on farmer arable land.

Biomass (stem, bark, branches and twigs) of forest trees is an important supplier of fodder, feed and fuel (Rawat and Nautiyal, 1988). The stem portion *Olea ferruginea shows maximum biomass (*49.01%) followed by branches (31.17%), leaves (1.98%), twigs (1.05%) and roots (16.65%). The biomass of this important species is used as fodder, feed and fuel (Abbas *et al.,* 2011). Similarly, *Acacia modesta* is a drought tolerant fodder tree and ideal for alleviating feed shortages of livestock. The present study estimated the effect of these two vegetation species *i.e*. *Acacia modesta* and *Olea ferruginea* cover for improving soil characteristics of the Dhrabi watershed in Pothwar region of Pakistan. As both the species have deep root system which is hypothesized to affect the soil of the area, we aimed at drawing the relationship between tree characteristics and its immediate effect on soil properties.

Materials and Methods

Study site: The Dhrabi watershed is located at 32° latitude and 72° E longitude. Upper catchment lies in the sub-district Kallar Kahar of Pothowar region (Fig 1). The area is sub-tropical semi-arid with mean annual rainfall of 460-640 mm (Shah, 2002) and 60% of the precipitation is received in monsoon. Maximum summer temperature is 41°C and winter has mean maximum temperature of 21 °C, occasionally falling to below zero (Anonymous, 2008). The general vegetation of the area is dominated by *Olea ferruginea* and *Acacia modesta* along with other tree types and grasses species.

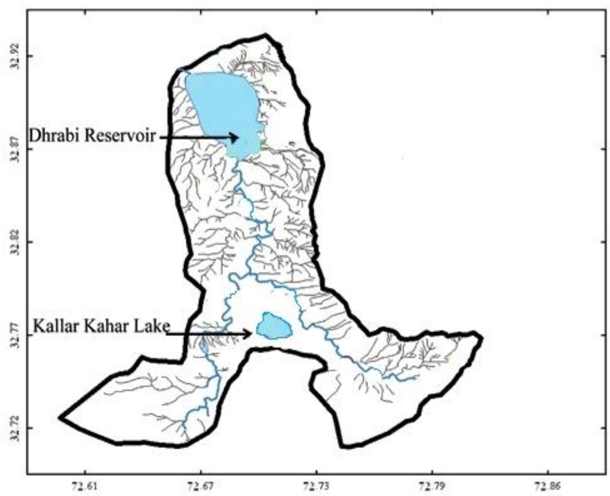

Fig 1. Location of sampling for soil analysis

Soil characterization: Four trees of both *Olea ferruginea* and *Acacia modesta* species were selected randomly from four different sites (agricultural and rangelands) and soil sample were collected from the depth of 0-15 cm, 16-30 cm, and 31-45 cm at various distances (of 1, 3, and 5 m) from tree trunk. Undisturbed soil core samples were used for calculating bulk density using method of Black and Hartge (1986) through 5 cm diameter double ring sampler from the genetic horizon. The air-dried, ground and sieved (2 mm) soil samples were used to determine basic soil properties *i.e*. texture, pH, NO_3, extractable P and K, and $CaCO_3$ were studied using methods of Page *et al.* (1982). For pH, 50 g of dried soil was added and mixed to 50 ml of d H_2O and pH was measured after one hour using soil pH meter (Mc Lean, 1982).

Total organic carbon (TOC) was determined by mixing 1 g of dried soil 1.0 N $K_2Cr_2O_7$ solution and 20 mL concentrated H_2SO_4. After 30 minutes, 200 ml de-ionized H_2O and 10 mL concentrated ortho-phosphoric acid was added and allowed to cool. Then 10-15 drops of diphenylamine indicator were added and titrated against 0.5 M ferrous ammonium sulphate solution until the color was changed from violet-blue to green (Walkley, 1947). Dissolved organic carbon (DOC) was analyzed by extracting soluble organic carbon from 1:5 soil water suspensions, filtering through 0.45 µm membranes and analyzing the extract by carbon analyzer (Tao and Lin, 2000).

Data analysis: Data obtained in soil samples from agricultural as well as range lands under *Oleaf erruginea* and *Acacia modesta* in summer and winter of 2015 for physiochemical properties *i.e*. EC, pH, bulk density total organic carbon (TOC), dissolved organic carbon (DOC), $CaCO_3$, availability of N, P, K and organic matter (OM) were subjected to statistical analysis. Means of both seasons were used in two-factor ANOVA without replication and correlation was computed using Excel 2010. A digital map of Dhrabi watershed was constructed using ArcGIS10.2.2 (ESRI, USA).

Results and Discussion

Effect on soil macronutrients: In the present study differences were observed in the soil properties under two perennial tree species *i.e*. *Olea ferruginea* and *Acacia modesta* from both agricultural land and rangeland. The response towards nutrient uptake and soil properties varied for both species. However, nitrogen availability in the soil was negligibly affected by the presence of these species. Though soil available nitrogen under *Olea* species was slightly higher (0.246 mg/kg) as compared to available nitrogen of soil under *Acacia* species at rangeland (0.234 mg/kg) but it was slightly lower under *Acacia* species at agricultural land (0.235 mg/kg). On the contrary, availability of phosphorous and potassium in soil was significantly affected by these species. Available phosphorus was considerably higher in soil taken under *Olea* species (6.36 mg/kg) at rangelands as compared to soils under *Acacia* under same conditions (5.55 mg/kg). However, quantity of available phosphorus was slightly higher in soils under *Acacia* species (5.61 mg/kg) as compared to soils under *Olea* species (5.54 mg/kg) at agricultural lands. Similarly, the amount of available potassium was significantly higher under soils of *Olea* species (118.23 mg/kg) as compared to *Acacia* species (104.88 mg/kg) at agricultural lands, while rangeland soils showed significantly higher available potassium under *A. modesta* species (121.02 mg/kg) as compared to the soils under *Olea* species (109.01 mg/kg) (Fig 2-4). Our results were in agreement with the results of Mudrak *et al.* (2010) who recorded maximum variation in soil properties that directly affected the growth and development of tree. The lower retention of macronutrients like P in agricultural land can be attributed to utilization of these elements due to their uptake and subsequent depletion in the soil. The study of Brady and Weil (2008) also supported our study describing that soils retain and release large amount of essential major nutrients like C, N and P in presence of trees that directly affect their availability to plants. Our study showed that both type of tree species affected the organic matter and soil properties directly. Similar results were also reported earlier by Angers and Caron (1998). According to them trees roots have direct effect on the formation of soil pores and aggregates. This effect of forest trees on soil composition was also described by Brady and Weil (2008) who noted that the extracellular roots exudates and litter affected soil structure, organic compounds amount and overall chemistry. The indirect effects of tree were described by Wardle (2006) who envisaged that roots litters and exudates affected the soil biota. They concluded that root exudates are useful for the growth of decomposer and it enhances the process of decomposition. According to Yuefeng *et al.* (2014) the land use change had direct affect on the soil carbon and microbial biomass carbon in low hills of north Yanshan mountains.

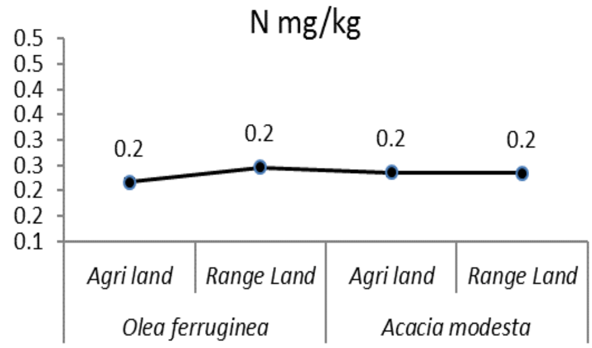

Fig 2. Nitrogen concentration in different soils under root zones of tree species

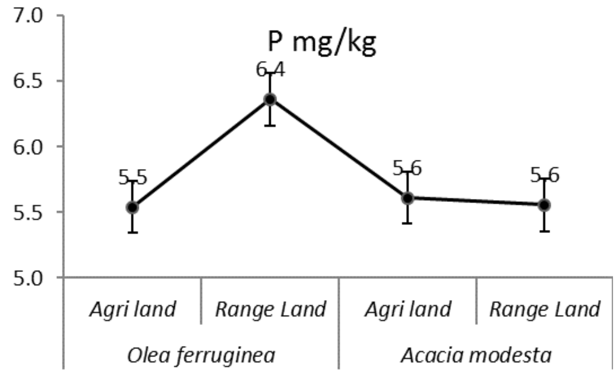

Fig 3. Phosphorus concentration in different soils under root zones of tree species

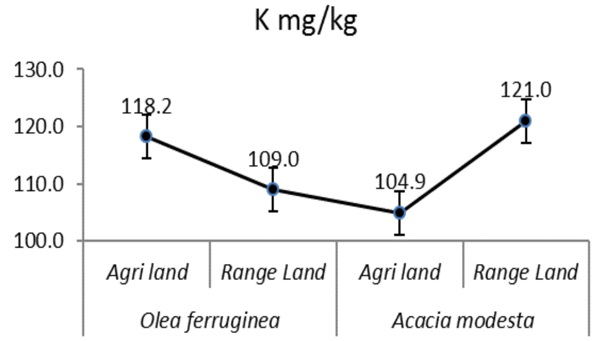

Fig 4. Potassium concentration in different soils under root zones of tree species

Effect on soil physio-chemical properties: In present study both the tree species had minor effect on soil physio-chemical properties (Table 1). Electric conductivity (EC) under *O. ferruginea* species was slightly higher (0.335 dS/m and 0.339 dS/m) as compared to soil under *A. modesta* species (0.29 dS/m and 0.30 dS/m) at both agricultural and rangelands, respectively (Fig 5). Soil organic matter (OM) under *Olea* species was slightly higher (0.49%) as compared to organic matter of soil under *Acacia* species (0.46%) at rangeland. Alternatively, it was slightly higher under *Acacia* species (0.46%) at agricultural land. A negligible effect of these species was observed on soils bulk density (BD) and pH. The pH of soils under *Olea* species was slightly higher than soils under *Acacia* species at both the land uses. Our data revealed that saturation percentage of soils at agricultural lands was significantly higher under *Olea* species (32.5%) as compared to soils under *Acacia* species (28.0%). However, saturation percentage of soils under *Acacia* species (38.83%) was significantly higher as compared to soils under *Olea* species (30.44%) at rangelands. Similarly, amount of total organic carbon (TOC) of the soils at agricultural lands was slightly higher (2.71 g/kg) under *Acacia* species as compared to soils under *Olea* species (2.5 g/kg). However, TOC of the soils under *Olea* species was higher as compared to soils under *Acacia* species at rangelands although difference was not significant. For dissolved organic carbon (DOC) no significant difference was observed among the soil samples taken under both tree species. However, soil DOC under *Olea* species was slightly higher (agricultural land: 226.2 mg/kg and rangeland: 205.2 mg/kg) as compared to DOC of soil under *Acacia* species at both land types locations (Fig 6). For agricultural lands, the amount of $CaCO_3$ of the soils was slightly higher under *Acacia* species (23.53 mg/kg) as compared to that under *Olea* species (23.05 g/kg). While $CaCO_3$ of the soils under *Olea* species was higher (rangeland: 23.60 g/kg) as compared to soils under *Acacia* species at rangelands, although difference was not significant. Our results were in conformity with the findings of Dawud *et al*. (2017) where they recommended the mixed forest of Douglas–fir and beech for soil improvement in North-Western parts of Europe. According to them, the combined therapy of these two plants species affected the properties of top soil. They found different responses of soil for presence of nutrients like C, N, and C/N ratio in combined and separate use of these plant species. They reported that beech in separate treatment decreases the amount of C and N in soil, while the other species increase this amount several times in at nutrient poor sites. In similar study, Mareschal *et al*. (2010) found that Douglas-fir has more forest flow mass and C content as compared to beech. The six trees species i.e. spruce, pine, larch, oak, lime, and alder had different effect on morpho-biochemical properties of soil. The soil forested with tree species had maximum litter and C/N ratio as compared to soil with deforested area. The soil with forest also had high C content, improved microbial growth, low microbial respiration rate, enhanced earthworm bioturbation (Frouz *et al*., 2013).

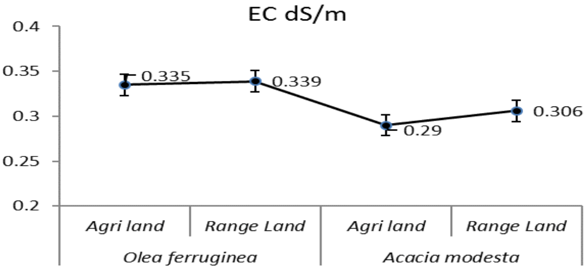

Fig 5. EC in different soils under root zones of tree species

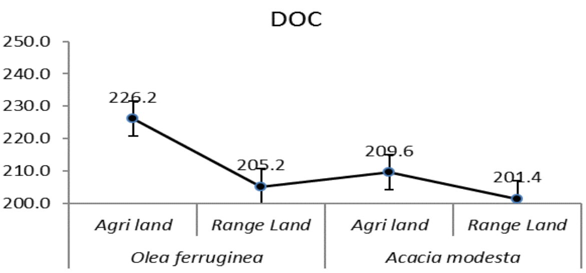

Fig 6. Concentration of dissolved organic carbon in different soils under root zones of tree species

Table 1. Physio-chemical properties of soil under *Olea ferruginea* and *Acacia modesta* tree species

Species	Location	N (mg /kg)	P (mg /kg)	K (mg /kg)	pH	EC (dS/m)	TOC (g/kg)	DOC (mg/kg)	$CaCo_3$ (g/kg)	Bulk density (g/cm^3)	OM (%)
Olea	Agri. land	0.22	5.54	118.23	7.82	0.335	2.50	226.2	23.05	1.35	0.433
ferruginea	Rangeland	0.25	6.36	109.00	7.83	0.339	2.83	205.2	23.60	1.55	0.491
Acacia	Agri. land	0.24	5.61	104.89	7.81	0.290	2.71	209.6	23.53	1.35	0.469
modesta	Rangeland	0.23	5.56	121.03	7.82	0.306	2.71	201.4	22.63	1.54	0.468
Mean		0.23	5.77	113.29	7.82	0.32	2.69	210.58	23.20	1.45	0.47
SD±		0.01	0.40	7.60*	0.01	0.02	0.14	10.92*	0.45	0.11	0.02

Table 2. Correlation between different soil characteristics for rangeland and agricultural land under *Acacia modesta* and *Olea ferruginea*

	N	P	K	pH	EC	TOC	DOC	$CaCo_3$	Bulk Density	OM
N										
P	0.76									
K	-0.53	-0.44								
pH	0.38	0.77	0.22							
EC	-0.08	0.55	0.25	0.85						
TOC	1.00	0.74	-0.52	0.36	-0.10					
DOC	-0.84	-0.36	0.15	-0.17	0.38	-0.86				
$CaCo_3$	0.47	0.63	-0.93	0.06	0.11	0.46	0.03			
Bulk Density	0.67	0.58	0.26	0.74	0.29	0.67	-0.75	-0.20		
OM	1.00	0.75	-0.52	0.37	-0.09	1.00	-0.85	0.46	0.67	

Correlation among soil parameters: A Pearson's correlation analysis was performed for all the studied soil parameters (Table 2). Highly significant positive correlation was found between nitrogen concentration and organic matter (1.0**) and total organic carbon (1.0**). Phosphorus had also significant positive association with higher pH (0.77**), TOC (0.74**), OM (0.75**), $CaCO_3$ (0.63*) and bulk density (0.58*). But highly significant negative association was observed between N and DOC (-0.84**), K and $CaCO_3$ (-0.93**), DOC and OM (-0.85**) and DOC and bulk density (-0.75**). Indeed, the bulk density is a basic physical property of soils and a good indicator of the soil porosity and elasticity, and also affected by different factors in the soils. In general, the low bulk density soil had better fertility attributes including soil nutrients and thus it promotes plant growth as well as soil organic carbon content (Tracy *et al*., 2013).

Conclusion

The present study provided insight into potential effect of *Olea ferruginea* and *Acacia modesta* tree species on physiochemical properties of soil from both agricultural and rangelands. It was observed that the prevalent *Acacia modesta* tree had little effect on the soil properties of adjacent root zone. The soil under this species exhibited lower cation exchange capacity, potassium and bulk density. But the soil characteristics i.e. organic matter and EC and macronutrients (NPK) availability were moderately improved under *Olea ferruginea.* This showed positive impact on soil physio-chemical properties, hence it can be exploited as potentially beneficial for plantation at agricultural as well as rangelands in Dhrabi watershed area, Chakwal-Punjab.

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