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EFFECTS OF TREE SPECIES AND DISTANCE FROM THE TREE ON SOME PHYSICAL AND CHEMICAL PROPERTIES OF AN ENTISOL IN SEMI-ARID ZONE OF NIGERIA

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ABSTRACT

Selective planting or maintaining trees in the farmer's field may recapture nutrients leached from the sub-soil and the decomposition of fallen leaves ensures recycling of nutrients. A study was conducted to determine the effects of four tree species and distance from the tree on physical and chemical properties of soils. Treatments consisted of four tree species (Parkia biglobosa, Faidherbia albida, Azadirachta indica and Acacia nilotica) and four different distances (2, 4, 6, and 8 m) from the base of trees. Sixteen composite soil samples (0-30 cm) and sixteen core soil samples (For bulk density determination) were collected for the study. Four composite and four core samples (at 2, 4, 6, and 8 m distance each) from the vicinity of each of the tree species were collected. Results showed no significant effect of the distance from the base of the trees on physico-chemical properties of the soils. However, soils between 2-4m distances tend to have better physico-chemical properties. Tree species had significant ($P<0.05$) effect on pH, total exchangeable bases (TEB), percentage base saturation (PBS), cation exchange capacity (CEC), total nitrogen (N), available phosphorus (P), bulk density (BD), particle density (PD), and porosity of the soils. Soils under P. biglobosa and F. albida had significantly ($P<0.05$) higher TEB, PBS and available P than A. indica and A. nilotica. Soils under P. biglobosa, F. albida and A. indica were better structured (low BD) than under A. nilotica and the soils under P. biglobosa and A. indica were more porous than F. albida and A. nilotica. Planting and maintaining P. biglobosa and F. albida could be more beneficial than A. nilotica and A. indica species in an Entisol in the semi-arid environment.

Keywords: Tree species; Soil physical and chemical properties; Entisol

INTRODUCTION

Trees can make a significant contribution to maintenance and restoration of soil fertility. Over the years farmers have come to realise that trees have certain desirable roles to play on the soils, which they use to cultivate agricultural crops, this was simply by noticing the performance of crops grown under trees with those grown beyond the canopies of trees. The soil beneath the trees develops a greater organic matter, and hence N content, and an improved ability to retain moisture (Dancette and Poulain, 1969). Trees have a deep rooting system and the maintenance of this deep rooting system in the soil can help to close up nutrient cycles as the trees act as ‘nutrient pump’ (Nye and Greenland, 1960) reducing losses by leaching and returning nutrients to the soil in leaf litter.

A number of researches have been carried out across the globe to determine the effects of trees on soil physical and chemical properties (Radwanski and Wickens, 1981; Bernhard-Reversat, 1982; Young, 1987). There is evidence that inclusion of compatible desirable tree species on farmlands can result in marked improvement in soil fertility. In a research conducted on sandy soil in northern Nigeria by Radwanski and Wickens (1981) pH, organic carbon, total N, and CEC were higher under a neem tree (Azadirachta indica) than on bare soil of the same land. In the Semi arid zone of northern Senegal, Bernhard-Reversat (1982) reported that soil organic C and total N decreased progressively from tree trunk to the canopy margin under Acacia senegal and Baobab (Andasonia digitata). This was attributed to soil enrichment by the two species due to the primary effect of their litter. Felker (1978) reported that for Faidherbia albida, cases of 50- 100% increase in soil organic C and N under the canopy were found. Soil fertility enrichment by trees could result from many causes. According to Young (1987), increase in soil organic carbon and nitrogen under the tree canopies were found to be as a result of flow from the tree trunk, preferential trapping of atmospheric inputs enhanced nutrient uptake from depth, reduction in leaching losses by the tree roots, biological nitrogen fixation and effects of animals and birds. Another major cause is addition of organic matter through carbon fixation in photosynthesis and its transfer via litter and root decay.

In another study in Senegal, yields of groundnut (Arachis hypogaea L.) were doubled beneath *F. albida* trees (Dancette and Poulain, 1969) and yield of sorghum (Sorghum bicolor (L.) Moench) and maize (Zea mays L.) were over 50% greater beneath trees than outside the tree canopy in eastern Ethiopia (Poschen, 1986). Similarly, a study based on the soil analysis was carried out to investigate the effects of tree species and distance from the tree on some physical and chemical properties of the soils.

MATERIALS AND METHODS

Study Area

The research was conducted in farmlands located within the premises of the Usmanu Danfodiyo University, Sokoto. Sokoto lies in the northwestern part of the country at latitude 13º 01’ N and longitude 05º 15’ E. It has a mean annual temperature of 27ºC in the coldest month of December and 38ºC in the warmest month of April with mean annual rainfall of 580 mm (Arnborg, 1988). The soils in the site of the current studies have been classified as Entisols (Noma and Yakubu, 2002).

Soil Sampling, Preparation and Analysis

The soil samples were collected at four distances near four different tree species namely: Faidherbia albida, Acacia nilotica, Parkia biglobosa and Azadirachta indica . The samples were taken at distances of 2 m, 4 m, 6 m, and 8 m away from the base of each tree. Core samples for bulk density determination were also collected using core samplers at similar distances. A total of 16 each of composite and core soil samples were collected for the study. The soils were air-dried, grounded and sieved using a 2 mm sieve before the analysis.

Soil pH was determined using 1:1 soil and water suspension ratio with electrode pH meter (Bates, 1954.) Particle size analysis was carried out using Bouyoucos hydrometer method as described by Day (1956).

Cation exchange capacity was determined using ammonium saturation method (Chapman, 1965). Organic carbon was determined using Walkley–Black method (Walkley and Black, 1934). Calcium and Magnesium were determined using EDTA titration as described by (Mclean, 1965). Sodium and potassium were determined by flame photometer (Rich, 1965). Total nitrogen was determined by macro-Kjeldahl method as described by Campbell (1978). Available phosphorus was determined using Bray – P1 method (Bray and Kurtz, 1945). Bulk density and Particle density were determined using core sampler and pycnometer methods, respectively.

Percentage base saturation and percentage pore space (Porosity) were calculated using the formulae below.

$$\text{Percentage Base Saturation} = \frac{\text{Total Exch. Bases (cmol/kg)}}{\text{Cation Exchange Capacity (cmol/kg)}} \times 100$$

$$\text{Percentage pore space (Porosity)} = 100 - \left(\frac{\text{Bulk Density}}{\text{Particle Density}} \times 100 \right)$$

Data Analysis

Data obtained were subjected to analysis of variance procedure (SAS, 2003). Means found to be significantly different were separated by least significance difference (LSD) test at 5% level of significance.

RESULTS AND DISCUSSION

Results showed significant effect of tree species on most of the parameters measured on soil physical and chemical properties. Distance from the base of the tree had no significant effect on the soil physico-chemical properties (Table 1).

Effect of Tree Species

Chemical properties

Tree species had significant ($P<0.05$) effect on the pH of the soil (Table 2). Highest pH of 7.89 (slightly alkaline) was recorded under P. biglobosa followed by F. albida (6.85, slightly acid) and *A. indica* (6.72, slightly acid) that recorded similar pH. Lowest pH of 6.28 (slightly acid) was recorded under A. nilotica. This variation in the pH could be due to leaching of the base forming cations from the soil.

Table 1. Probability values of effect of tree species and distance from the base of the tree on some physical and chemical properties of the Entisol.

Physico-chemical characteristics	Tree Species	Distance	CV (%)
Degree of freedom	3	3	
pH 1:2 (H_2O)	0.0001	0.8456	2.9
Exchangeable bases (cmol kg^{-1})			
Ca	0.1982	0.2196	22.3
Mg	0.0090	0.3556	13.6
Na	0.2581	0.7114	13.7
K	0.1298	0.4363	17.0
T.E.B.	0.0018	0.1875	11.5
P.B.S. (%)	0.0029	0.0957	12.1
C.E.C (cmol kg^{-1})	0.0010	0.3834	4.7
O.C (g kg^{-1})	0.1401	0.9345	8.7
Total N (g kg^{-1})	0.0010	0.5339	17.5
Available P (mg kg^{-1})	0.0012	0.0950	6.6
B.D (g cm^{-3})	0.0017	0.4692	1.7
P.D (g cm^{-3})	0.0001	0.4813	1.0
Porosity (%)	0.0001	0.6899	1.8

T.E.B = Total exchangeable bases, P.B.S = Percentage base saturation, C.E.C = Cation exchange capacity, B.D = Bulk density and P.D = Particle density

Table 2. Effect of tree species on some chemical properties of the Entisol.

Physico-chemical characteristics	Tree species			
	Parkia biglobosa	*Faidherbia albida*	*Azadirachta indica*	*Acacia nilotica*
pH 1:2 (H2O)	7.89[a]	6.85[b]	6.72[b]	6.28[c]
Exch.bases (cmol kg^{-1})				
Ca	0.97	1.11	0.79	0.85
Mg	1.66[a]	1.70[a]	1.05[b]	1.09[b]
Na	0.09	0.10	0.10	0.10
K	0.03	0.02	0.03	0.03
T.E.B.	2.74[a]	2.94[a]	1.97[b]	2.07[b]
P.B.S. (%)	32.46[a]	32.83[a]	25.44[b]	21.68[b]
C.E.C (cmol kg^{-1})	8.42[bc]	9.00[ab]	7.80[c]	9.55[a]
O.C (g kg^{-1})	1.4	1.4	1.6	1.6
Total N (g kg^{-1})	0.6[a]	0.4[b]	0.3[b]	0.4[b]
Available P (mg kg^{-1})	1.99[b]	2.42[a]	1.85[b]	2.02[b]

Means in a row followed by same letters are not significantly different at 5% level using LSD; T.E.B =Total exchangeable bases, P.B.S.=Percentage base saturation and C.E.C=Cation exchange capacity.

It's possible that A. nilotica had less ground cover than *P.biglobosa*, *A.indica* and and *F. albida* leading to direct contact with the rain resulting into leaching of base forming cations.

Total exchangeable bases (TEB).

Total exchangeable bases were significantly (P<0.05) affected by tree species. Significantly higher TEB was recorded under *F. albida* (2.95 cmol kg^{-1}) and *P. biglobosa* (2.75 cmol kg^{-1}) than under *A. nilotica* (2.07 cmol kg^{-1}) and *A.indica* (1.97 cmol kg^{-1}) species (Table 2). This could be associated to the pH of the soil that resulted from decomposition of litter from the different species hence influencing the status of the base forming cations. This was evident from the individual analysis of the bases particularly Ca and Mg cations (Table 2).

Percentage base saturation (PBS)

The PBS was significantly (P<0.05) affected by the tree species with higher PBS under F. albida (32.83%) and P. biglobosa (32.46%) than under *A. indica* (25.44%) and *A. nilotica* (21.68%) (Table 2). PBS as explained earlier could be associated to the pH of the soils since as pH of the soil under *F. albida* (6.85) and P. biglobosa (7.89) was higher than under *A. indica* (6.72) and *A. nilotica* (6.28). Moreover, F. albida and *P. biglobosa* might have produced higher leaf litter resulting in the release of higher Ca and Mg in the soil. Greater root expansion thus greater ability to recycle or recapture nutrients from deep soil to the surface soil could be responsible for higher PBS in F. albida and P. biglobosa.

Cation exchange capacity (CEC)

Data on CEC indicate low range of values beneath the trees. Values ranged from 7.8-9.55 cmol kg^{-1} soils implying that the soils had a very low capacity to retain cations and may strongly encourage leaching. CEC was significantly affected by the tree species with A. nilotica (9.55 cmol kg^{-1}) and *F. Albida* (9.00 cmol kg^{-1}) recording significantly (P<0.05) higher CEC than *P. biglobosa* (8.42 cmol kg^{-1}) and A. indica (7.8 cmol kg^{-1}) (Table 2). This could probably be due to the variation in the soil texture and humus content. Since the humus content (Organic carbon) was similar under all the tree species (Table 2), it is possible that *A. nilotica* and *F. albida* had greater canopy spread and root expansion. Greater canopy spread may prevent direct contact of the rain with soil and thus leaching and greater root expansion binds the soil particles and recaptures nutrients from the deep soil to top soil.

Total nitrogen (N)

Nitrogen content of the soil was generally very low and was significantly affected by the tree species. *P. biglobosa* (0.6 g kg^{-1}) had significantly (P<0.05) higher N content than other three species (0.3-0.4 g kg^{-1}) (Table 2). *P. biglobosa*, *A. nilotica* and *F. albida* being a legume had the ability to fix N_2 from the atmosphere. Thus, litters (senesced leaves) from these species (particularly *P. biglobosa*) released higher N into the soil when decomposed than A. indica (non-legume) species (Table 2).

Available phosphorus (P)

Available P was generally very low and was significantly affected by tree species. Soils beneath *F. albida* (2.42 mg kg^{-1}) had significantly (P<0.05) higher available P than the other three species that had similar available P content in the soil (1.85-2.02 mg kg^{-1}). This implies relatively higher fertility status of the soils. Soils beneath *F. albida* were near neutral (6.85) and at this pH both HPO_4^{-2} and $H_2PO_4^-$ may be found in equal amounts and readily available for plant uptake as reported by (Brady and Weil, 1999).

Physical Properties

Soil texture

The particle size distribution of the soils showed that the sand fraction which ranged from 938.7-957.1 g kg^{-1} dominated the soil beneath all the tree species. It is obvious from the results that the clay and silt content of the soil (0-30 cm) was very low, thus giving rise to sandy texture of the surface soil. Although, the tree species is not likely to affect the soil texture beneath but the sandy nature of these soils may encourage the leaching of the bases through the macropores in the rainy season. Such soils will be poor in moisture retention capacity even during the rainy season as reported by Odunze, 1990 in similar study in a different environment.

Bulk density (BD)

BD was significantly affected by tree species with soils beneath *A. nilotica* (1.76 g cm^{-3}) recording significantly ($P<0.05$) higher BD than other three species (1.65-1.67 g cm-3) that had similar BD (Table 3). Lower BD suggests a more structured soil with more pore space thus better aeration while higher BD suggests that the soils are comparatively less structured or there is compaction of the soil. This variation in the BD under different tree species could be attributed to the amount of litter dropped from the tree species, their canopy spread and root expansion. Only few studies have compared soil physical properties under trees although the higher carbon would be expected to cause improvement to these (Young, 1997). Lower bulk densities and higher water infiltration rates were reported in Kenya (Belsky, 1994).

Particle density (PD)

The particle density was significantly ($P<0.05$) higher beneath *A. nilotica* (2.97 g cm^{-3}) than the other three species. Among the three species, soils beneath *P. biglobosa* (2.89 g cm-3) and *A. indica* (2.87 g cm^{-3}) had significantly ($P<0.05$) higher PD than *F. albida* (2.64 g cm^{-3}) (Table 3). A high value of PD (>limits of 2.60-2.75 g cm^3) suggests that the soils had less organic matter and more of high-density minerals. Little organic matter in the soil could be due to the continuous cultivation of the soil beneath the tree and also due to washing off of the loosely held organic matter because the soils beneath the trees had greater proportion of sand particles.

Porosity

Porosity of the soil beneath *A. indica* (42.25%) and *P. biglobosa* (42.22%) was significantly ($P<0.05$) higher than the soils beneath *A. nilotica* (40.70 %) and *F albida* (36.10 %) (Table 3). High porosity is known to promote root growth by increased aeration and water infiltration (Brady and Weil, 1999). Therefore, soils under *P. biglobosa* and *A. indica* were more conditioned than *F albida* and *A. nilotica*.

Table 3. Effect of tree species on some physical properties of the Entisol

Tree species	Sand ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Clay ($g\ kg^{-1}$)	Bulk Density ($g\ cm^{-3}$)	Particle Density ($g\ cm^{-3}$)	Porosity (%)
Parkia biglobosa	938.7 c	35.6	25.7 a	1.67b	2.89b	42.22a
Faidherbia albida	957.1 a	27.4	15.5 b	1.67b	2.64c	36.10c
Azadirachta indica	944.8 bc	30.7	24.5 a	1.65b	2.87b	42.25a
Acacia nilotica	949.1 ab	29.5	21.4 a	1.76a	2.97a	40.70b

Means in a column followed by the same letters are not significantly different ($P>0.05$).

Effect of Distance

Distance from the base of the tree had no significant effect on soil physico-chemical properties (Table 4). However, 2 and 4 m distance from the base of the tree had slightly higher total exchangeable bases, percentage base saturation, organic carbon, available phosphorus, bulk density and porosity

Table 4. Effect of distance from the tree base on some physico-chemical properties of the Entisol.

Physico-chemical characteristics	Distance (m) from the base of the tree			
	2 m	4 m	6 m	8 m
pH 1:2 (H_2O)	6.92	6.89	6.91	7.01
Exch.bases ($cmol\ kg^{-1}$)				
Ca	1.06	1.04	0.79	0.84
Mg	1.31	1.52	1.30	1.36
Na	0.18	0.29	0.19	0.26
K	0.03	0.03	0.03	0.03
T.E.B.	2.50	2.67	2.22	2.33
P.B.S. (%)	29.66	31.35	25.13	26.29
C.E.C ($cmol\ kg^{-1}$)	8.45	8.57	8.90	8.85
O.C ($g\ kg^{-1}$)	0.16	0.15	0.15	0.15
Total N ($g\ kg^{-}1$)	0.4	0.4	0.4	0.4
Available P ($mg\ kg^{-1}$)	2.06	2.19	1.94	2.08
B.D ($g\ cm^{-3}$)	1.68	1.69	1.68	1.71
P.D ($g\ cm^{-3}$)	2.84	2.85	2.83	2.86
Porosity (%)	40.34	40.24	40.65	40.02

T.E.B = Total exchangeable bases, P.B.S = Percentage base saturation, C.E.C = Cation exchange capacity, B.D = Bulk density and P.D = Particle density

Similar studies by Dunham (1991) have reported higher N, P, Mg, and Ca for soils under trees while Frost and Edinger (1991) and Tomlinson et al., (1995) reported high CEC values for soils at the vicinity of some tree species.

Distance from the base of the tree had no significant effect on the soil pH but it tends to be slightly acid at the base of the tree (6.92) than away from the tree (7.01) (Table 4). This is contrary to the findings of Sae-Lee et al (1992) who reported higher pH values for soils under trees than those away from the trees. However, Karama and Haque (1992) reported no significance in pH of soils under *Faidherbia albida* in moist humid, highlands Vertisols of Ethiopia. They reported higher C, N, P and K for soils under the tree than away from the trees.

Distance from the base of the tree had no significant effect on other parameters like total nitrogen, available phosphorus, potassium and organic carbon content. This could possibly be due to continuous cultivation of the land in the area of study.

The annual crops continuously used up nutrients in the soils leading to uneven distribution of nutrients in a soil as a result of continuous cultivation. Karama and Haque (1992) obtained similar results for N and P content in the continuously cultivated soil of Ethiopia highlands.

CONCLUSION

Distance from the base of the tree had no significant effect on any soil physico-chemical parameters analysed. However, tree species had significant effect on most of the soil physico-chemical parameters measured. Soils beneath *P. biglobosa* and *F. albida* had significantly higher TEB, PBS and available P than A. indica and A. nilotica. Soils under *P. biglobosa, F. albida and A. indica* were better structured (low BD) than under *A. nilotica* and the soils under *P. biglobosa* and *A. indica* were more porous than *F. albida* and A. *nilotica*. Therefore it could be concluded that planting and maintaining *P. biglobosa* and *F. albida* might be more beneficial than *A. nilotica* and *A. indica* species in the Semi-arid environment.

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