IJMAAS International Journal of Microbiology and Applied Sciences
ISSN 1115-4004 *Volume 3 issue 1 Jan, 2024* Research Article

Physicochemical Studies of Rhizosphere soil of *Acacia senegal* and *Acacia seyal* in a Semi Arid Region in Nigeria

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ABSTRACT

This investigation was carried out to determine the physico-chemical properties of soils under *Acacia senegal* and *Acacia seyal* stands, in Government Secondary School, Tambuwal as a case study in semi-arid zone of Nigeria. Soil samples were collected systematically in three replications at two depths of 15cm and 30cm at each sampling site under the tree canopies. Soil samples outside the tree canopies served as control. The experiment was laid in a 2x3 factorial experiment in completely randomized design (CRD). Samples were analyzed for pH, Electrical conductivity (EC), Organic carbon (OC), Nitrogen (N), Phosphorous (P) and Potassium (K). Statistical analysis was performed on the data obtained, using Duncan Multiple Range Test (DMRT) at 5% for mean separation. The result for mean pH value showed that the control sample recorded a mean pH value of 6.7 which was significantly different from the mean pH values of soil samples collected under the canopy of *A. senegal* (6.26) and *A. seyal* (6.39) The mean values for Electrical conductivity for *A. senegal* (61.97S/m). *A. seyal* (43.47) and the control (46.00) showed no significant difference ($P \leq 0.05$). The effect of depth and the interaction between the depths was observed to have no significant difference for N. It can be deduced from this present study that leguminous tree species improve the soil physical and chemical properties.

Keywords: *Acacia senegal*, *Acacia seyal*, physicochemical properties, soil fertility, tree stands, soils, factorial design

Introduction

Soils in semi-arid regions are known for their low fertility and susceptibility to degradation mostly through wind erosion. However, there had been the practice of incorporating agroforestry trees with the annual crops cultivated by farmers in the region. Leguminous trees play a very significant role in nutrient inputs in agroforestry systems which they achieve through biological fixation and deep nutrient capture (Sanchex, 2018). Crops grown around the rooting zone of these trees have been shown to access high level of nitrogen and a reduction in nutrient losses from erosion and leaching (Buresh and Steven, 2004). *Acacia senegal* and *A. seyal* are some of the most grown trees in the region because of their adaptation to the harsh environmental conditions. *Acacia senegal* is a leguminous tree found in most African countries including Nigeria. It is a multipurpose tree grown for its high grade gum production. Also it is now used in soil fertility improvement as well as fuel and fodder production in rural communities (Clark and Williams, 2009). Its extended lateral root system plays significant role in soil stabilization and possibly nitrogen fixation and mineral enrichment from the leaf litter (Eish *et al*., 2018).

Acacia senegal has been shown to improve some physical and chemical properties of soils under its tree canopies (Shehu and Aliy, 2009). The tree litter has also been shown to improve organic matter content as well as N, P, K, Ca, Mg and Na (Abdullahi, 2019). *Acacia seyal* is also a leguminous tree species indigenous to the arid and semi-arid regions, it is of the family Fabaceae, (Mimoseae). It is a nitrogen fixing species (Eish *et al*. 2018), its bark provides valuable forage for cattle and game, while the leaves and pods are used for fodder (Dorthe, 2009).

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Materials and Methods

Study Area (Experimental Site)

Soil samples were collected in the rhizosphere of *Acacia senegal* and *A. seyal* located around the premises of Government Secondary School, Tambuwal, Sokoto State, Nigeria. The area lies within latitude 11^0 to 15^0E and longitude 10^0 to 25^0N. The study area is hot and dry for the greater part of the year with temperature range of between 15^0C to 20^0C minimum and 37^0C to 47^0C maximum. The vegetation is largely covered with grasses and a few sparsely distributed drought resistant tree species. The season composes of dry and wet seasons with rainfall ranges of 500-800cm annually and evaporation of 240mm per year (SSG, 2017).

Soil Sample Collection and Sampling Method

Two soil samples of 1kg each were systematically collected at a distance of 15m under the canopy of the *A. senegal* and *A. seyal* in the grooves with two other samples of 1kg each; also collected in an adjacent areas not covered by the canopy of the species to serve as control. The soil samples were collected at two depths of 15cm and 30cm from each selected sampling point, into air-tight polythene bags; labeled I and II respectively. The bags were subsequently transported to the laboratory in Department Biological Sciences, Usman Danfodiyo University Sokoto, Nigeria.

Soil Analysis

Each of the soil samples collected was replicated three times and they were separately passed through 2mm sieve to remove extraneous materials before analysis. The following physico-chemical properties of the soils were analyzed.

Hydrogen Ion Concentration (pH)

The pH of the soil was measured by the supernatant suspension of a 1:5 (Soil:Liquid) mixture using pH meter with glass electrode. 20g of each soil sample was measured into 100ml plastic bottle; 50ml of distilled water was added and the bottle was covered with its lid and shook for 2 hours. Before opening the bottle for measurement, it was also shook by hand twice and an electrode was immersed in the upper part of the suspension. The pH was taken with a pH meter when the mixture was stable (Bray and Kurtz, 2005).

Electrical Conductivity (EC)

The Electrical conductivity was determined with a conductivity cell by measuring the electrical resistance of a 1:5 soil water suspension with conductivity water and cell in bottles. The mixture was prepared by weighing 10g of the soil into a bottle that has 50ml distilled water. This mixture was shaken vigorously with hand for one hr to dissolve the soluble salts. The calibrated conductivity meter was used to obtain the cell constant. The value indicated on the conductivity meter was recorded (Walkley and Black, 2005).

Nitrogen Assay

Nitrogen assay was carried out using microkjeldhal method (Bremner, 1995). One gram (1g) of each of the soil samples was weighed into a digestion tube; 2.5ml of digestion mixture was added and 1ml of hydrogen peroxide was also added. The tubes were placed on the heater and heated for 1hr at moderate temperature 200^0C. The temperature was turned up to 330^0C and the heating continued until the mixture was transparent after two hr. The tubes were then removed from the heater and allowed to cool. The mixture was later distilled by adding 20ml of boric indicator solution in a beaker on a stand beneath the condenser tip. The beaker was removed from the distiller; condenser tip was rinsed and titrated distillate with 0.011m HCI until colour changed from green to pink. The percentage of nitrogen was calculated from the formular below:

$$\% \mathbf{N} = \frac{a-b}{S} \text{ x M 1.4 x mcf}$$

Where:

a= ml HCI required for titration sample
b= ml HCI required for titration blank
S= air-dry sample weight in gram
M= Molarity HCl
$1.4x10^{-3}$ x 100% (14 = atomic weight of nitrogen)
mcf= moisture correction factor.

Total Phosphorus Assay

Total Phosphorus assay was determined by using the method of Bray and Kurtz (2005). In this method 5.0 g of each soil sample and pinch of P free charcoal were mixed with 50 ml of each extract in dry and clean plastic bottles. The solution was shaken manually for 2 min and filtered with Whatman filter paper. The extracted phosphorus was measured with colorimeter based on the reaction with ammonium molybdate. The absorbance of the compound was measured at 882 nm in a spectrophotometer.

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Total Potassium Assay

Total Potassium assay was determined by using flame emission spectrophotometer method (Jackson, 2000). Five (5) g of each oven-dry soil samples were put into 250 ml conical flasks. Exchangeable bases were then extracted from the soil samples by introducing 100 ml of 0.4 m Lithium chloride acetate in each flask. The extractions involved shaking for 2 hrs and filtering using a suction pump. The filtrates collected were then analyzed for potassium.

Experimental design and statistical analysis

Experimental design and statistical analysis for the investigation was 2×3 factorial in a completely randomized design. Data obtained from all the variables were subjected to analysis of variance (ANOVA) using statistical package for agricultural research (AGRES). Significant difference in the treatments was further subjected to Duncan Multiple Range Test (DMRT) for separation of the means.

Results

The results for the mean values of the tested physico-chemical parameters and the analysis of variance of the data obtained in this investigation are presented in Tables 1 and 2 respectively. The result for mean pH values showed that the control sample (pH 6.7) was not significantly different from the soil samples collected under the canopy of *A. senegal* (pH 6.3) and *A. seyal* (pH 6.4) ($P \leq 0.05$).

The mean values of EC for *A. senegal* and control (61.97, 43.47 and 46.00) showed no significant difference ($P \leq 0.05$) in the value, although the values for *A. senegal* was higher than for *A. seyal* and the control sample (Table 1). Analysis of variance also showed no significant difference in the depth and their interaction for EC (Table 2).

Although, the mean N% for *A. seyal* and *A. senegal* (0.31 and 0.18) were considerably higher than those of the control sample (0.46) and there was no significant difference in the values of ($P \leq 0.05$) (Table 1). The effect of depth and interaction between the treatment and depth was also observed to have no significant difference of N. The values recorded for organic carbon showed significant difference among all the three treatments ($P \leq 0.05$). *A. senegal* gave the higher mean value of 0.34, *A. seyal* (0.18) and control (0.04).

The depths of collection of soil samples as well as the interaction between the treatment and depth showed no significant difference for organic carbon (Table 2). The P value for *A. seyal* (19.96) significantly different from the value of *A. senegal* (15.44), while *A. senegal* differs significantly from the control (5.95) (Table1).

The result for potassium shows soil samples collected under *A. senegal* (0.36) significantly different from those under *A. seyal* (2.25) and control (0.17). The effect of depth and interaction between treatments and depth were not significant ($P \leq 0.05$) (Table 2). Significant differences were observed only in nitrogen, organic carbon and phosphorus (Table3).

Table 1: Mean values of physico-chemical constituents in rhizosphere soils of *A. senegal*, *A. seyal* and control at depth of 15 cm

Sources of variation	**Physicochemical Parameters of Rhizosphere soils**					
	pH	**EC (S/m)**	**N (%)**	**OC (%)**	**P (ppm)**	**PMeqk^{+}/100g**
Acacia Senegal	6.27^{c}	62.00^{a}	0.19^{c}	0.34^{d}	15.44^{b}	0.36^{d}
Acacia seyal	6.39^{c}	43.47^{b}	0.31^{d}	0.18^{e}	20.00^{b}	0.24^{d}
Control	6.70^{c}	46.00^{b}	0.05^{f}	0.04^{f}	5.95^{c}	0.17^{c}
S.E	1.01	1.00	1.90	1.91	1.00	1.00

*Means in a column followed by the same letter are not significantly different using DMRT at 5%level.
Key: EC= Electrical Conductivity, OC= Organic Carbon, N= Nitrogen

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Table 2: Means values of physicochemical constituents of rhizosphere soils of *A. senegal*, *A. seyal* and control at depth of 30 cm

Sources of variation	Physicochemical Parameters of Rhizosphere soils					
	pH	**EC (S/m)**	**N (%)**	**OC (%)**	**P (ppm)**	**PMeqk$^+$/100g**
A. Senegal	6.25^c	61.90^a	0.17^e	0.34^d	15.51^b	0.34^d
Acacia seyal	6.29^c	43.46^b	0.31^d	0.17^e	19.90^b	0.25^d
Control	6.70^c	46.11^b	0.04^d	0.04^f	5.93^c	0.17^e
S.E	1.01	1.00	1.00	1.01	1.00	1.00

*Means in a column followed by the same letter are not significantly different using DMRT at 5%level.
Key: EC= Electrical Conductivity, OC= Organic Carbon, N= Nitrogen

Table 3: Analysis of variance of the effects of trees species on physicochemical constituents of soil

Sources of variation	Physicochemical parameters of rhizosphere soils						
	DF	**pH**	**EC (S/m)**	**N (%)**	**OC (%)**	**P (ppm)**	**PMeqk$^+$/100g**
Treatment	2	6.6^{ns}	0.59^{ns}	1.69*	47.53*	26.54*	7.50*
Depth	1	0.11^{ns}	0.50^{ns}	0.78^{ns}	0.92^{ns}	0.85^{ns}	0.19^{ns}
Treatment Depth	2	0.02^{ns}	0.85^{ns}	1.17^{ns}	1.87^{ns}	1.47^{ns}	0.25^{ns}
Error	12						
Total	17						

Key: EC= Electrical Conductivity, OC= Organic Carbon, N= Nitrogen; ns=not significant; *=Significant

Discussion

All the pH values recorded from the soil samples were significantly high and lack effect on *A. senegal* trees. This is in conformity with the findings of Andrew *et al*. (2021) who recorded a similar result from physio-chemical parameters of soil sample collected from *Parkia biglobosa* canopy in Kontangora, Niger State. The N value in the control area was higher as a result of the disposition of blown leaf litter from adjoining trees as reported by Kamara and Hague (2020). The higher values of organic carbon recorded under *Acacia senegal* and *Acacia seyal* canopies can be attributed to the litter fall which increased the organic content of the soils as reported by Raddad *et al*. (2019) in symbiotic nitrogen fixation in *Acacia senegal* in dry land clays in Sudan. The results from organic carbon showed considerable input of phosphorus from the effect of the trees. The effects of depth as well as the interaction between depth and the interaction was however not significant (P≤0.05)

In conclusion, *Acacia senegal* and *Acacia seyal* are leguminous trees and this present study has shown that these trees improve various soil physical and chemical properties.

This investigation has shown differences in the values of organic carbon, ppmP, and meqk$^+$ in soil sample collected under the canopies of *A. senegal* and *A. seyal* compared to the samples collected in their control plots. The effects of depth of collection of soil samples and the interaction between treatments and the depth of collection were not significant.

It is therefore advocated that the government and other relevant agencies should popularize the cultivation of these economic tree species for soil fertility management practice. These trees are endowed with features that give them potentials for ecosystems stabilization and for desertification control.

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