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EFFECT OF *PAKIA BIGLOBOSA* TREE *(DURAWA)* ON SOIL FERTILITY IN SOME SELECTED SMALLHOLDER FARMS IN GWANDU LGA, KEBBI STATE, NIGERIA

BY

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ABSTRACT

The study was carried out to assess the effect of Parkia biglobosa tree on soil fertility in some selected smallholder farms in Gwandu Local Government Area of Kebbi State, Nigeria. Ten (10) isolated trees each of Parkia biglobosa species grown on similar site conditions were selected at random on farmer's farms for the research. Radial distance based soil sampling (under the canopy, near to the canopy and outside the canopy) was adopted for the research work. Experimental design used was 1x3 arrangements of treatments (three radius) in Randomized Complete Block Design (RCBD) replicated 10 times (10 scattered trees of each species). A total of sixty (60) composite soil samples were taken for each species at two (2) different depths (0-15cm and 15-30cm) respectively, and at three (3) distances (radius) in four (4) different directions (north, south, east and west) of each tree. The soil samples collected were analyzed for soil texture, soil reaction (pH), Cation Exchange Capacity (CEC), soil organic carbon, total nitrogen, available phosphorus, potassium calcium, magnesium and sodium to assess fertility status of the soil. The analyzed results showed high level of soil organic carbon and total nitrogen under the canopies of Parkia biglobosa tree species. Soil pH was slightly low under Parkia biglobosa. Available phosphorus and calcium recorded low status while Cation Exchange Capacity, potassium, magnesium and sodium recorded medium status and Soil total nitrogen recorded high status. In term of soil physical properties, soil under P. biglobosa was found loamy sand under all the three canopy positions. Further study on the factors responsible for the low level of some soil nutrients under the canopies of P. biglobosa tree in the study area is recommended.

Key words: Pakia, soil fertility, smallholder farms, Gwandu

1.0 Introduction

Conventionally in modern agriculture, increased productivity has been achieved mainly through application of synthetic inorganic fertilizers. However, the increasing price of synthetic fertilizers and the inability of poor farmers to gain access to them pose severe constraints on their widespread use. Although organic matter may be an alternative source of nutrients, neither animal manure nor green biomass is usually found in adequate quantities to meet the high application rates (10–40 Mg ha^{-1} $year^{-1}$) required to meet the nutrient requirements of crops (Mafongoya, *et al.*, 2006). Improving fertilizer use efficiency by a combination of organic and inorganic nutrients is vital to the long-term sustainability of global agriculture. Within this important goal there is great potential for the more effective utilization of biological N-fixation (BNF), which is virtually without cost. BNF accounts for 60% of N production (Zahran, 1999) and 16% of the current global Nitrogen (N) input (Liu *et al*., 2010). However, in Africa and South America, BNF is the single largest Nitrogen (N) source, accounting for 32–34% of the Nitrogen (N) input (Liu *et al.*, 2010). In this respect its further use would, at the least, ease the pressure for land through the rehabilitation of degraded areas (Herridge *et al.*, 2008). However, BNF can also play a greater role in sustainable agriculture as it increases Nitrogen (N) recovery rates in addition to reducing the need for synthetic fertilizers.

Lack of soil fertility restoring resources, soil erosion and unequal soil fertility management have been reported to contribute to soil fertility depletion in arid Africa (Bationo *et al.*, 2007; Vanlauwe and Giller, 2006). Leguminous trees that are nitrogen fixing trees are known to play complementary or alternative role as source of organic fertilizer and have the potential to sustain soil fertility (Giller, 2001; Snapp, *et al.*, 2003; Adjei-Nsiah, *et al.*, 2004).

The use of fertilizer tree like *Faidherbia albida* has been documented in semi-arid Africa, north and south of the equator, from southern Algeria to Transvaal and from the Atlantic to the Indian Ocean (Kirmse and Norton, 1984). It has been promoted in agroforestry as its characteristic reverse phenology allows satisfactory production of crops under a full stand of the species (Roupsard, *et al.*, 1999). Tree leaves are shed at the onset of the rainy season which significantly reduces the shade cast beneath the trees and reduces competition for water (Kirmse and Norton, 1984), light and nutrients (Kho, *et al*, 2001) with associated crops grown during the rainy season.

Conservation Agriculture (CA) promoters contend that integrating *Faidherbia albida* trees into Conservation Agriculture systems based on the three principles of minimum tillage, diversified crop rotations and permanent soil surface cover enhances the soil improving benefits of Conservation Agriculture as not only does *Faidherbia albida* fix nitrogen, it also returns other nutrients to the soil and increases Soil Organic Matter (SOM) content through the shedding of its nutrient-rich leaves and the subsequent decomposition of its leaf litter at the onset of rains (Saka, *et al.*, 1994).

Many crops can benefit from being planted under African locust bean (*Parkia biglobosa*) canopy: maize, cassava, yams, sorghum and millet (Orwa, *et al.*, 2009).African locust bean trees provide shade for forage grasses and livestock. They protect the soil from heat and wind and are potent nutrient cyclers from the deep soil layers. They bind soil particles and therefore have a potential merit in silvopastoral systems. Leaf shed provides litter and hence organic matter to the soil. As livestock stands under the trees, they fertilize the soil with their dung (NRC, 2006; Sina *et al*., 2002; Campbell-Platt, 1980). Foliage of locust bean has been found to contribute to soil fertility improvement. In an experiment, the isolated relative effect of locust bean in the third year of the experiment was 86%, compared to 138% for neem, a related tree (Uyovbisere and Elemo, 2002). The relative index of soil productivity during this time clearly appreciated for locust bean, as well as the accumulation of Phosphorus (P) and organic Carbon (C) compared with neem (Uyovbisere and Elemo, 2002).

1.2 Statement of the Problem

Nutrients replacement using mineral fertilizers is a limited option for many smallholder farming households of the study area. This is because, increasing price of synthetic fertilizers and the inability of poor farmers to gain access to them pose severe constraints on their widespread use.

However, leguminous tree such as *Parkia biglobosa* that is nitrogen fixing tree is known to play a complementary or alternative role as a source of organic fertilizer and have the potential to sustain soil fertility. The contribution of this tree to soil fertility enhancement is not adequately studied in the study area. Hence, this study examined the effects of *Parkia biglobosa* tree on soil physical and chemical properties in the study area following a radial distance gradient method from the tree trunk.

1.3 Justification of the Study

Implementing agroforestry systems in resource-poor farming households is considered to mitigate soil nutrient mining. Integration of legume trees into agricultural systems, therefore, adds biologically fixed nitrogen and other agriculturally important nutrients to the soil in a way that complements the crops grown in association with the trees. These trees are also known to bring about changes in edaphic, micro-climatic, and other components of the ecosystem through bio recycling of mineral elements, environmental modifications (including thermal and moisture regime), and changes in floral and faunal composition.

1.4 Objectives of the Study

The main objective of the study is to examine the effect of *Parkia biglobosa* tree on soil fertility in some selected smallholder farms in Gwandu Local Government Area, Kebbi State, Nigeria.

The specific objectives are to:

1. assess the effect of *Parkia biglobosa* on soil physical properties in the study area
2. determine chemical properties of soil (Soil pH, SOC, CEC, TN, AVP, K, Ca, Mg and Na) in the study area.

2.0 Materials and Methods

2.1 The Study Area Description

The study was conducted in Kebbi State Nigeria around Anguwar Kade and Gwabbare Sakke Villages respectively all in Gwandu Local Government Area. Geographically, the study area lies between latitude $12^0$30'8" North and longitude $4^0$38'33" East, and the area falls within the Sudan savanna ecological zone and characterized by the open woodland with scattered trees such as *Parkia biglobosa, faidherbia albida, Adansonia digitata, Acacia nilotica, Khaya senegalensis etc.* The average annual temperature of the area is 32^{0c}, annual precipitation in the area averages 900mm, while the humidity level of the area is at an average of 26% (Anon, nd). As of 2006, the estimated population of Gwandu LGA is one hundred and fifty one thousand, and seventy seven people (151,077) NPC (2006), inhabitants with the majority of the area's populace made up of members of the Fulani and Hausa ethnic divisions. The Fufulde and Hausa Language are extensively spoken in the area while the religion of Islam is commonly practiced in the area. Farming is the major occupation of the people of Gwandu

LGA with crops such as Groundnut, Rice, Millet, Sorghum, Onions, Late millet and sugar cane grown in large quantities in the area. Trade also booms in the area with the LGA hosting several markets such as the Dodoru market where the area's dwellers go to buy and sell a plethora of commodities. Other important economic activities that are popular in Gwandu LGA include cattle rearing and the making and sales of the popular kilishi snack (Anon, nd).

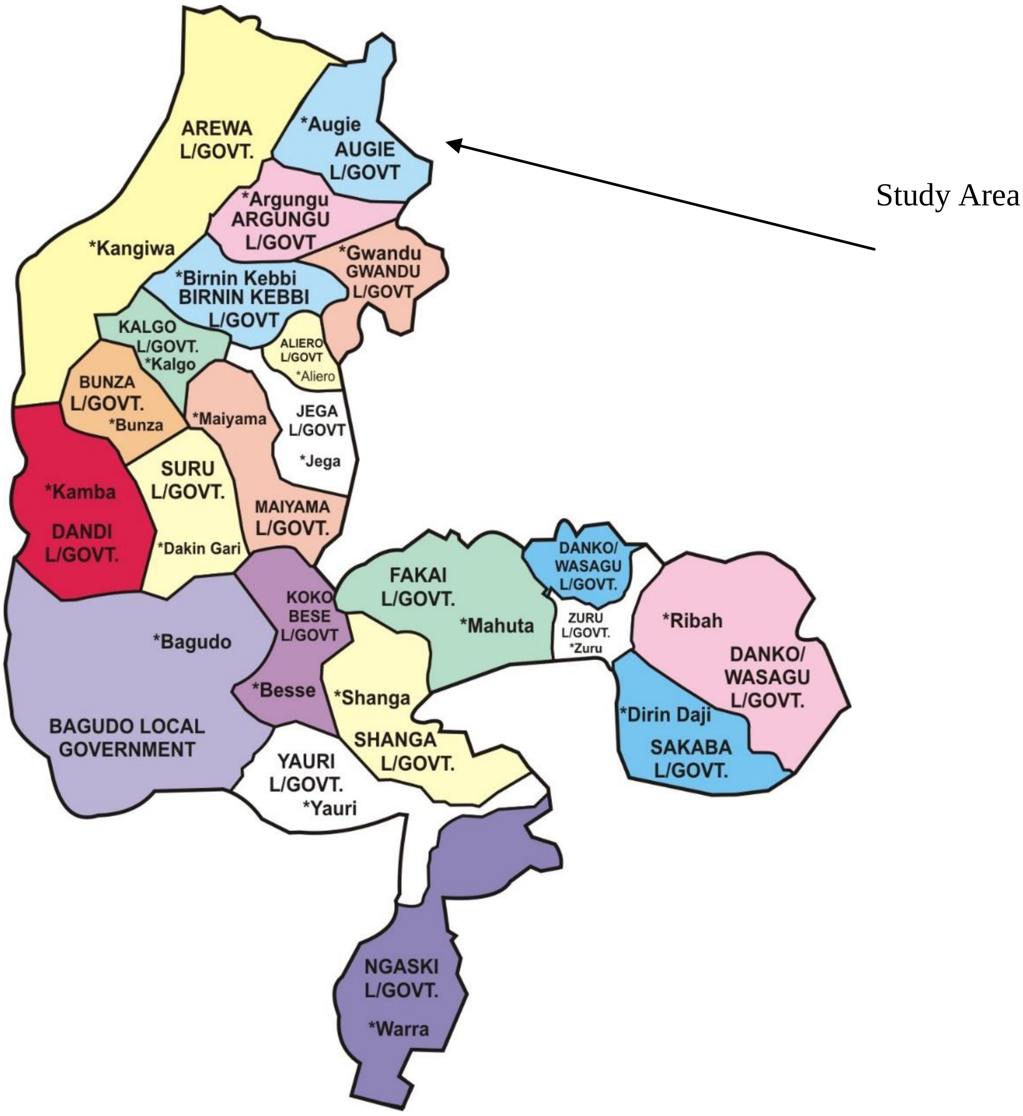

Fig. 1: Map of Kebbi State Showing Location of the Study Area (Gwandu LGA)

2.2 Field layout and Experimental Design

The study was conducted on farmer's field to assess the soil fertility status under the canopy cover and outside the canopy cover of *Pakia biglobosa*. To collect data on soil physical and chemical properties, ten (10) isolated trees of the species grown on similar site conditions were randomly selected on farmer's farms. Radial distance based soil sampling (under the canopy, near to canopy and outside the canopy) was adopted (Figure 2). Three canopy positions, one at 50% of the canopy radius (from the tree trunk, called mid canopy), second at 50%at the extreme end of the canopy (from the mid canopy position, called canopy edge) and the third at 100% much beyond the canopy (far away from the canopy edge, called canopy gap) were demarcated. Experimental, design used was 1x3 arrangements of treatments (three radius) in Randomized Complete Block Design (RCBD) replicated 10 times (10 scattered trees of each species).

2.3 Data Collection

A total of 60 composite soil samples were taken at two different depths (0-15cm and 15-30cm) at three distances (radius) in four different directions (North, South, East and West) of each tree. The soil samples collected were analyzed for soil texture, soil reaction(pH), soil organic carbon (SOC), cation exchange capacity (CEC), total nitrogen (TN), available phosphorus (AvP), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) to assess soil fertility status.

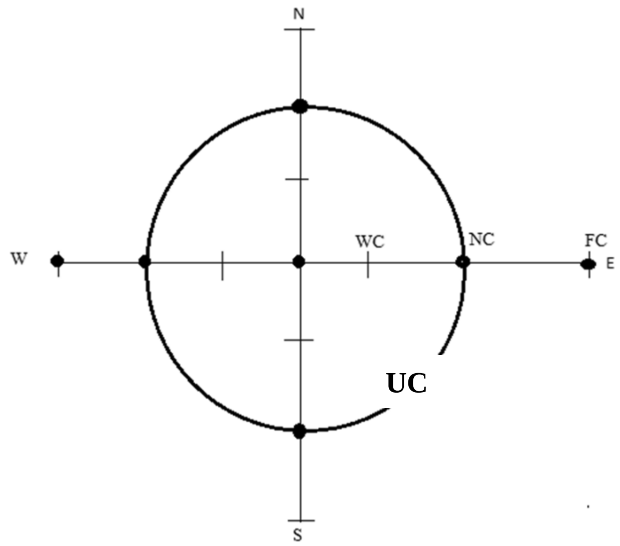

Fig. 2: Design of Soil Sampling where N is North, S is South, E is East, W is West, UC is under the canopy, NC is near to the canopy edge and FC is far away to the canopy.

2.4 Soil Laboratory Analysis

Soil laboratory analysis was conducted on the following parameters:
Soil organic carbon (SOC) was analyzed using the walkley-Black Oxidation method (Chesworth, 2008), total nitrogen (NT) using the Kjeldhal method (Jackson, 1958), available phosphorus (AvP) using the Olsen method (Olsen and Sommers, 1982), cation exchange capacity (CEC) using the ammonium acetate method (Houba, *et al.,* 1989), soil reaction (pH) was determined using a pH meter (Van Reeuwijk, 1992). Soil particle size (soil texture) composition was analysis using the hydrometer method (Bouyoucos, 1962). Flame photometer method (Jackson, 1958) was used to determine potassium (K) and sodium (Na) of the soil, calcium (Ca) and magnesium (Mg) concentration of the soil was determined using atomic absorption spectrophotometer (Jackson, 1958). Data generated from soil analyses is presented in the results tables in chapter four.

3.0 RESULT PRESENTATION

The results of some physical and chemical properties of the soil are shown in tables 3.1 and 3.2 and the interpretation was based on recommendations of Esu (1991), Bruce (1997) and FAO (2021).

Table 3.1: Soil Textural Classes of Different Canopy Positions under *Parkia biglobosa Species* at 0-15cm and 15-30cm Soil Depths

	Mid Canopy				Canopy Edge				Canopy Gap			
					Parkia biglobosa							
0-15	82.55	9.04	8.41	Loamy Sand	83.34	8.61	8.05	Loamy Sand	83.94	8.24	7.82	Loamy Sand
15-30	85.69	8.63	5.68	Loamy Sand	87.46	6.87	5.67	Sand	86.85	7.67	5.48	Sand
Mean	**84.12**	**8.84**	**7.05**	**Loamy Sand**	**85.4**	**7.74**	**6.86**	**Loamy Sand**	**85.40**	**7.96**	**6.65**	**Loamy Sand**

Sources: Field data 2021

The result (Table 3.1) shows that mid canopy, canopy edge and canopy gap positions recorded loamy sand textural class.

Table 3.2: Soil Fertility Status of Different Canopy Positions under *Parkia biglobosa* Tree Species at 0-15cm and 15-30cm Soil Depths

Soil Depth	Soil PH	Organic C.	CEC	Total N.	Avail. Phosphorus	Potassium	Calcium	Magnesium	Sodium
					Mid Canopy				
(cm)		**(g/kg.)**	**(Cmol./kg)**	**(g/kg)**	**(mg/kg)**	**(Cmol./kg)**	**(Cmol./kg)**	**(Cmol./kg)**	**(Cmol./kg)**
0-15	5.94	25.90	10.9	0.64	0.59	0.19	1.77	0.91	0.31
15-30	5.99	26.40	9.9	0.58	0.59	0.18	1.24	0.61	0.25
Mean	**5.97**	**26.15**	**10.4**	**0.61**	**0.59**	**0.19**	**1.51**	**0.76**	**0.28**
Fertility Status	**Medium Acidic**	**High**	**Medium**	**High**	**Low**	**Medium**	**Low**	**Medium**	**Medium**
					Canopy Edge				
0-15	6.12	26.40	10.6	0.63	0.59	0.14	1.68	1.03	0.29
15-30	6.11	26.00	9.8	0.55	0.57	0.12	1.05	0.62	0.23
Mean	**6.12**	**26.20**	**10.2**	**0.59**	**0.58**	**0.13**	**1.37**	**0.83**	**0.26**

Fertility Status	**Slightly Acidic**	**High**	**Medium**	**High**	**Low**	**Medium**	**Low**	**Medium**	**Medium**
				Canopy Gap					
0-15	5.89	14.70	10.0	0.61	0.58	0.16	1.56	0.92	0.25
15-30	5.97	15.00	9.3	0.54	0.57	0.15	1.18	0.65	0.18
Mean	**5.93**	**14.85**	**9.7**	**0.58**	**0.58**	**0.16**	**1.37**	**0.79**	**0.22**
Fertility Status	**Medium Acidic**	**Medium**	**Medium**	**High**	**Low**	**Medium**	**Low**	**Medium**	**Medium**

Source: Field data 2021

The result (Table 3.2) present *Parkia biglobosa* tree species soil fertility status at different canopy positions. The pH of the soil under mid canopy and canopy gap was found medium acidic, while the pH of the soil under canopy edge was slightly acidic. The fertility status of organic carbon in the soil under the mid-canopy and canopy edge was found high, while medium fertility status was recorded under canopy gap. Available phosphorus and calcium recorded low fertility status at mid canopy, canopy edge and canopy gap respectively. Cation Exchange Capacity (CEC), potassium, magnesium and sodium recorded medium status. Total nitrogen was found high under canopy positions.

DISCUSSION

4.1 Effect of *Parkia biglobosa* Tree on Soil Physical Properties

The soil textural class is an important characteristic of a soil and gives a general picture of the soil physical property (Prasada and Power, 1997). The textural class of the soil in the study area was found loamy sand at mid-canopy and canopy edge under *Parkia biglobosa* and outside (canopy gap) (Table 3.1). The findings of this study are consistent with those of Emmanuel and Albert (2018) who reported that there were no significant differences between the soil under and outside *Parkia biglobosa* canopy with respect to the mean proportions of sand, silt and clay in the 0-10cm layer. Similarly, there were no significant differences between soil under and outside *Parkia biglobosa* canopy with respect to soil textural composition of the 10-20cm layer. The soils under and outside *Parkia biglobosa* canopy are texturally similar.

4.2 Effect of *Parkia biglobosa* Tree on Soil Chemical Properties

The pH of the soil under *P. biglobosa* (Table 3.2) shows that canopy edge position of *Parkia biglobosa* tree species was slightly acidic while the mid canopy and canopy gap recorded medium acidic status. These findings conformed with Mafongoya *et al*. (2006) who reported that increases in soil pH in acid soils have been associated with application of tree prunnings. According to Kamara and Haque, 1992 fertilizer trees could minimize soil acidification both by decreasing drainage and recycling leached nutrients. The level of organic carbon was high at mid-canopy and canopy edge, while canopy gap recorded medium status (Table 3.2) this could be due to accumulation of leaf litter under the Pakia canopy. The result of this study conformed to the findings of various researchers (Nyberge and Hogberg 1995, Tadesse et al., 2001, Abebe et al., 2001, Zebene and Goran Agren, 2007) who reported an increase in soil organic carbon under the trees compared to away from trees. Also according to Abebe, (2006), there was significant decrease in soil organic carbon with increasing distance away from the tree trunk in Harerge highlands, Ethiopia.

The total nitrogen recorded high status level (Table 3.2) under the three canopy positions and this agreed with the findings of Emmanuel and Albert (2018), who reported that, there were no significant differences between the soil under and outside *Parkia* canopies with respect to soil total nitrogen status in both the 0-10cm and 10-20cn layers. They further said that, this should be expected as there was no significant accretion of organic matter in the soil under *Parkia* canopy. The results of this finding which indicate accumulation of high nitrogen under *P. biglobosa* tree canopy disagreed with the findings of Buba (2015), who compared the properties of soil under and outside the canopy of locust bean trees (*Parkia*) in the Guinea Savanna zone of Nigeria and recorded no significant build-up of total nitrogen under the tree canopy. Available phosphorus in the soil under all the canopy positions of *Parkia biglobosa* tree species was low as indicated in (Table 3.2). The result of this study agreed with the findings of Emmanuel and Albert (2018) who reported low available phosphorus status (1.32-1.70 mg/kg) in the soil under and outside *Parkia* canopy at both 0-10cm and 10-20cm soil layers. Also according to them, the low phosphorus status of the soils can be adduced to the practice of burning prior to cultivation, savanna vegetation burning during the fallow period and the slow rate of organic matter accretion in savanna fallow soil.

The concentrations of Cations Exchange Capacity (CEC) level was found medium (Table 3.2) under the canopy positions of *Parkia biglobosa* tree species and outside canopy. The results of this finding agreed with the findings of Emmanuel and Albert (2018) who reported that, there was an increase in the mean level of cation exchange capacity (CEC) in the 0-10cm layer of the soil under *Parkia* canopy. Also according to them, in the 10-20cm layer, there was a significant increase in cation exchange capacity (CEC) in the soil under the tree canopy. Potassium, Magnesium and Sodium levels under the two canopies and outside the canopy were found at medium level status (Table 3.2), the findings disagreed with the findings of Augustine and Joseph (1992) who reported that, the mean soil content of the exchangeable cations, calcium, potassium and sodium in the soils under the tree canopies was higher than that in the open. Whereas, Calcium under the tree canopy positions and outside was found low and this contradict findings of Augustine and Joseph (1992) who reported high levels of calcium under Pakia canopy.

Conclusion

Parkia biglobosa increases soil organic carbon and total nitrogen under its canopies and the study also indicated that there was a dominance of slightly to medium acidic soils under *Parkia biglobosa* tree in the study area with medium level of cation exchange capacity, potassium, magnesium and sodium and low level of available phosphorous, calcium. The textural class of the soil in the study area was found loamy sand at mid-canopy and canopy edge under *Parkia biglobosa* and outside (canopy gap)

4.3 Recommendations

Based on these research findings, the following recommendations were made:

1. Farmers should Retain *Faidherbia albida* tree on their farms for its importance in soil fertility enhancement so as to improve food security of their households.

2. Crops that can tolerate slightly to medium acidic soils should be cultivated near and under the canopies of *P. biglobosa*.
3. Further study on the factors responsible for low level of some soil nutrients under the canopies of *Parkia biglobosa* in the study area is recommended.

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