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SOIL FERTILITY ASSESSMENT OF A SHEA (Vitellaria*paradoxa* C.F. Gaertn) FIELD AT BIDA, NIGER STATE

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ABSTRACT:

Knowledge of the fertility status of soils is basic to managing them for optimum crop production. Fertility status of a cultivated Shea (Vitellaria *paradoxa* C.F. Gaertn) field was assessed at Bida, Niger state. Soil samples were collected using auger and core methods, air-dried, sieved with a 2-mm sieve and analyzed for physical and chemical properties in the laboratory using standard methods. The results when compared with soil fertility classes for upland crop cultivation and soil characteristics for tropical soils indicated that organic matter, ECEC and exchangeable potassium were low. The study further revealed that base saturation percent cannot be relied upon as an indicator of soil fertility alone as its values could be influenced by exchangeable sodium. Integrated Fertility Management (IFM) approach has been suggested as ways of improving the fertility status of the soils for sustainable Shea tree cultivation in the area.

Key Words: Bida**,** Integrated fertility management, NIFOR, Shea tree, Soil fertility.

INTRODUCTION:

The fertility of a soil depends on its physical, chemical and biological properties. Physical biological and chemical properties of soils play significant role in crop production. A soil that supplies adequate nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and micronutrients with favourable soil pH will produce plant of good quality and yield if other conditions of growth such as biological and physical properties of the soil are favourable (Anderson, 1991). Soils are not just to supply adequate nutrients alone but the nutrients to be in proper balance (Ayeni and Adeleye, 2011). Nitrogen helps in chlorophyll formation and plant growth though its excess in relation to other nutrients such as P, K and S can delay crop maturity while phosphorus is known to help in root growth, seed formation and quick ripening of fruits (Ayeni and Adeleye, 2011). Calcium helps in pectate formation and tuberization (Anonymous, 1993). Calcium may antagonize available phosphorus if they are not in balanced proportions. Also sodium and potassium have negative interactions. Changes in soil pH will result in numerous interactions where one ion or nutrient interferes with or competes with the uptake and utilization of other nutrients by plants.Soil fertility research and management therefore is primarily concerned with the essential plant nutrients- their amounts, availability to crop plants, chemical reactions that they undergo in soil, loss mechanisms, processes making them unavailable or less available to crop plants, and ways and means of replenishing them in soils (Prasad and Power, 1997).

The Shea tree (*Vitellaria paradoxa*) is known to grow in the wild and its natural habitat stretches over Africa, South of the Savanna, from the eastern part of Senegal to the North of Uganda. This stretch covers an area of over 5,000km long and 400-750 km wide (Oviasogie, Oko-boh and Oseghe, 2012). In Nigeria, the Shea tree also occurs in the wild and thrives well in the Guinea Savannah areas as well as the Lower Sahel ecology (World Agroforestry Center, 2008).The dried nut from the tree is used for the production of edible vegetable fat, medicinal and personal care products. The tree is therefore very important in the rural health care and the rural economics in the Sudano-Sahelian regions of Africa.

At the Nigerian Institute for Oil Palm Research Substation at Bida in Niger State, Nigeria, research activities on all areas of the Shea tree are on-going. These areas include reduction of gestation period through appropriate grafting methods and soil fertility studies and management. This study seeks to provide information on the fertility status of the soils supporting Shea tree at the Substation with a view to making recommendations for fertility management of the soils.

MATERIALS AND METHODS

Study area

This study was conducted at the Nigerian Institute for Oil Palm Research Substation, Bida, Niger State. The area falls within the Southern Guinea Savannah zone of Nigeria and is located on Latitude 08^0 05.278'N and Longitude 006^0 47.789'E with annual rainfall ranges between 500mm to 1200mm per annum. Minimum and maximum temperature ranges between 24^0C and 33^0C respectively. The site is generally flat with the presence of a few ant hills. The major land use types in the area are arable crop production intercropped in Shea tree parklands. The Shea field used for this study was over fifteen years old.

Field studies:

Several representative soil samples were obtained at two depths with the aid of a soil auger from a field cultivated to the Shea tree. Samples obtained at surface depth (0-15cm) were bulked into a composite, mixed thoroughly and replicated three times. This procedure was repeated for the subsurface soil (15-30cm). Soil samples obtained at surface and subsurface depths were air-dried and sieved with a 2- mm sieve. The samples that passed through the 2-mm sieve were analyzed in the laboratory for physical and chemical properties as follows:

Laboratory analysis

Physical properties: Particle size distribution was determined by the hydrometer method as described by Boyoucous (Gee and Or 2002). Bulk density was determined by the core method (Blake and Harge, 1986) while total porosity of the soil samples was calculated from the relationship % F = (1- Bd/Pd) X 100

Where F = porosity

Bd = bulk density g/cm^3

Pd = Particle density of the soil estimated at 2.65g/cm^3 while available water at field capacity was determined by the method of Klute (1986).

Chemical properties: Soil organic carbon was determined by the Walkley-Black method (Nelson and Sommer, 1996). Total nitrogen (TN) was determined by Kjeldahl (Bremner, 1996) method. Soil pH was determined using a pH meter (Hendershot*et al*., 1993). Available phosphorus was extracted by the Bray-1 extractant (Bray and Kurtz, 1945). Soil exchangeable bases were extracted by the ammonium acetate method buffered at pH 7 (Thomas, 1982). Calcium and magnesium were read with the aid of a UV2100 Spectrophotometer while potassium and sodium were read with a flame photometer. Cation exchange capacity (CEC) was by the summation of exchangeable bases. Total exchangeable acidity, hydrogen and aluminium ($H^+ + Al^{3+}$) was by titration method (Anderson and Ingram, 1993) while effective cation exchange capacity (ECEC) was determined by summation of exchangeable cations and exchangeable acidity ((Kamprath,1970; Mylavarapu and Kennelley, 2002). The base saturation was calculated as the ratio of exchangeable bases to the effective cation exchange capacity (ECEC) expressed in percentage while the exchangeable sodium percentage (ESP) was computed as the ratio of Na to CEC expressed in percentage (Brady and Weil, 1999).

Statistical analysis: Data obtained from the laboratory was subjected to One- way analysis of variance (ANOVA) and the Least Significance Difference (LSD) procedure at 5% level of probability was used to separate the means.

RESULTS AND DISCUSSION:

Effects of soil texture on soil fertility

The textural classes are the intrinsic properties of the soil, which are sufficiently permanent and are often used to characterize the soil physical make up (Hillel, 1980). The texture of the soils was predominantly sandy (Table 1). Soils with sandy textures are either derived from Aeolian deposits parent materials, sandstones or shale and usually reflect the dominance of quartz in the soils parent materials. These soils are low with respect to nutrient and water retention. Sand and silt decreased with increasing soil depth while clay increased with increasing soil depth (Table 1).The silt/ (silt + clay) ratios were low and less than unity in both soil depths. This indicates that most of the silt has weathered into clay. According to Stewart *et al*., (1970), low silt and low silt/ (silt + clay) ratios are indicators of advanced weathering which arises from prolonged action or strong intensity of the weathering agents such as rainfall and temperature. The bulk density was $1.54 g/cm^3$ at both top and sub soils which was relatively high. The high bulk density values recorded in both soil depths could be attributed to the very low organic matter contents observed in both soil depths. According to Umeugochukwu *et al*., (2012), organic matter had the tendency of reducing bulk density as they recorded lower bulk density values with high organic matter content in their study of impact of soil erosion on land degradation in Uga, South Eastern Nigeria.High bulk density values have been reported for Savanna region of Nigeria (Ike, 1986).

Total porosity was 58% and was observed to be the same at both soil depths which implies that both soil depths had equal pore spaces. Increases in total porosity are often correlated with decreased bulk density. That trend was not observed in this study because of the similar bulk density values recorded at both soil depths. Moisture retention capacity of the soil was highest at the sub soil with a value of 25.3% while the top soil had a value of 23%. Both values suggest that the soils have the capacity to retain water.

Table 1: Particle size distribution and some selected physical properties of the soils

Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Bulk Density g/cm^3	Moisture Retention (%)	Porosity (%)	Silt/(Silt + Clay)	Textural Class
0-15	953.33	243.33	234.33	1.54	23.0	58	0.51	Sand
Cv%	0.61	8.55	16.88	-	-	-	-	
15-30	946.67	230.00	260.00	1.52	25.3	58	0.47	Sand
Cv%	0.61	4.33	16.76	-	-	-	-	
LSD (5%)	NS	NS	NS	NS	NS	NS	NS	

Table 2: Chemical Properties of the soils at Bida, Niger State

Depth (cm)	pH	O.C g/kg	TN	Avail P mg/kg	Ca	Mg	Na	K cmol/kg	ECEC	Ex. Acidity	Base Sat (%)	ESP (%)	SO_4 mg/kg	Ca/Mg	CN
0-15	5.50	3.6	0.20	11.15	1.05	0.49	0.32	0.10	2.43	0.51	81.20	12.82	5.25	2:1	18:1
CV%	1.82	2.8	5.0	0.09	0.95	2.04	3.33	10.0	0.41	-	2.14	-	0.33	-	-
15-30	5.30	3.0	0.12	6.05	1.06	0.87	0.49	0.12	2.65	0.41	88.29	16.22	7.96	1:1	25:1
CV%	1.89	3.3	8.33	0.16	1.96	6.99	2.13	8.33	0.38	-	3.44	-	0.19	-	-
LSD (0.05)	0.2	0.2	0.02	0.02	NS	0.10	0.02	0.02	0.02	0.02	5.61	0.29	0.05		

CHEMICAL PROPERTIES OF THE SOILS OF BIDA SUBSTATION

Soil pH, Organic matter, Total nitrogen, C/N ratios and available P.

Table 2 shows the chemical properties of the soils of the Shea field at Bida. The result shows that soil pH was moderately acidic at both soil depths and decreased significantly with increasing soil depth. When compared with soil fertility class and upland crop cultivation and soil characteristics for tropical soils (Table 3), soil pH was high in fertility with mean values of 5.50 and 5.30 in the top and sub soils respectively. Soil pH range between 5.0 and 6.5 is regarded as being high in fertility for tropical soils (Udo *et al*., 2009). Organic matter was higher at the top soil than the sub soil and decreased significantly with increased soil depth (Table 2). The amount of organic material in a soil is often expressed as the amount of organic carbon (Bridges 1978;Ogeh and Osiomwan, 2012). The values were low in fertility when compared with soil fertility classes for upland crop cultivation and soil characteristics for tropical soils (Table 3). This implies that the soils of the Shea field at Bida will require soil management measures that will enhance the accumulation of organic matter in the soils. Total nitrogen in the soils decreased with increasing soil depth (Table 2).C/N ratios were wide in both the top and sub soils (Table 2). According to Udo *et al*., (2009), wider C/N ratios indicate that nitrogen is immobilized by soil organisms. Generally Savanna Soils have lower N status and wider C/N ratio than Forest soils which greatly affect N availability (Enwezor *et al*., 1990). This may have accounted for the low nitrogen status of the soils. Available phosphorus was high in fertility at the top soils and medium in fertility at the sub soils when compared with soil fertility classes for upland crop cultivation and soil characteristics for tropical soils (Table 3). It decreased with increasing soil depth (Table 2). At soil pH of 5.5, phosphorus is likely to be available for uptake in tropical soils whereas at soil pH between 4 and 4.5, P is likely to be fixed by the oxides of Fe and Al. This suitable soil pH is the likely reason for high and medium P fertility at the top and sub soils of the Shea field at Bida.

Exchangeable Bases and Ca/Mg ratio

The exchangeable bases (Ca, Mg, Na and K) which are shown in Table 2 increased with increasing soil depth.

Mean Ca values were below critical levels at both soil depths. According to Enwezor *et al*., (1990), the critical level of calcium in soils of Southwestern Nigeria is 1.50 cmol/kg.
Mean Magnesium values were however above the critical levels in both soil depths (Table 2). However, a Ca/Mg ratio of 2:1 and 1:1 at the top and subsoils respectively indicates a possible P inhibition and Ca deficiency. According to Udo *et al*., (2009), a Ca/Mg ratio <3:1 indicates possible P inhibition and Ca deficiency in soils. The Ca/Mg ratio of a soil indicates that either the soil has low exchangeable calcium and normal magnesium or the soil has normal exchangeable calcium with high magnesium. A high Ca/Mg ratio indicates either too little magnesium relative to calcium or calcium is excessive relative to magnesium (Schulte and Kelling, 2010).
Exchangeable K was low in fertility in both soil depths when compared with Soil fertility classes for upland crop cultivation and soil characteristics for tropical soils (Table 5).

Exchangeable Acidity, Exchangeable Sodium Percentage, Effective Cation Exchange Capacity and Base Saturation Percent.

Exchangeable acidity values were 0.51cmol/kg and 0.41cmol/kg at both the top and sub soils respectively. These values were low at both soil depths and decreased significantly with increasing soil depth while exchangeable sodium percentage was the reverse of exchangeable acidity as it increased with increasing soil depth with values of 12.82% and 16.22% at both top and sub soils respectively.These values indicate the presence of excessive exchangeable sodium in the soil's exchange complex especially at the sub soil. The presence of excessive amounts of sodium in the soil (sodicity), especially at the sub soil leads to decreased permeability to water and air and poor soil drainage over time (Brady and Weil, 1999). This may have accounted for the fairly high bulk density values recorded at both soil depths. High exchangeable sodium percentage values have been reported for the Arid and Semi-arid regions of Nigeria which is mainly due to the process of incomplete sodium leaching owing to a short fall in the rains (FMANR, 1990).The effective cation exchange capacity (ECEC) was 2.43cmol/kg and 2.65cmol/kg at the top and sub soils respectively (Table 2). Both are in the low fertility class when compared with soil fertility classes for upland crop cultivation and soil characteristics for tropical soils (Table 3). Base saturation was 81.20% and 88.29% at both top and sub soils respectively (Table 2), indicating high fertility with respect to base saturation

Table 3: Soil Fertility Classes for Upland Crop Cultivation and Soil Characteristics for Tropical Soils

Characteristic	Soil fertility class			Fertility Status/Class of a Shea (Vitellaria *paradoxa* C.F. Gaertn) field at Bida, Niger State.
	High	Medium	Low	
pH (H_20)	5.0-6.5	4.5-5.5 or 7.5 -7.8	4.0 -4.5 or 7.8-8.0	High
Organic Matter (%)	> 3	1-3.0	< 1	Low
ECEC (meq/100g) or cmol/kg	>15	8-15	< 8	Low
Base Saturation (%)	> 70	50 -60	<50	High
Bray P-1 (mg/kg)	> 10	6 – 10	< 6	Medium-High
Exchange K meq/ 100g or cmol/kg	> 0.4	0.15 – 0.4	< 0.15	Low

(Source FAO 1976; Udo*et al*., 2009)

Table 4: Ranking of soil properties by coefficient of variability (CV) of top and sub soil

Ranking	Range of CV	Top soil properties	Range of CV	Sub soil properties
Least variable	< 15%	Soil pH, Organic carbon, N, P, Ca, Mg, Na, K, Ex acidity, ECEC, BS, SO_4, Sand and Silt.	< 15%	Soil pH, Organic carbon, N, P, Ca, Mg, Na, K, Ex acidity, ECEC, BS, SO_4, Sand and Silt.
Moderately variable	15-35%	Clay	15 – 35%	Clay
Extremely variable	> 35%	Nil	> 35%	Nil

Based on the ranking of soil nutrients by coefficient of variability (CV) of the top and sub soils, soil pH, organic carbon, total nitrogen, phosphorus, calcium, magnesium, sodium, potassium, exchangeable acidity, effective cation exchange capacity, base saturation percent, sulphate, sand and silt were least variable at both soil depths being less than 15% (Wilding 1985). While clay was moderately variable at both soil depths (Table 4).

CONCLUSION:

The fertility status of a Shea field was assessed at Bida, Niger state. The results indicated that organic matter, effective cation exchange capacity (ECEC) and exchangeable potassium were low. This study further revealed that base saturation percent cannot be relied upon as an indicator of the fertility status of a soil alone as its values could be influenced by exchangeable sodium. It further revealed the need for Integrated Fertility Management (IFM) approach if these soils are to sustain the cultivation of Shea on a long term basis. Such approaches should include the application of farmyard manure, planting of nitrogen fixing trees and application of calcium and potassium bearing minerals coupled with irrigation facilities to reduce the influence of incomplete sodium leaching. Further studies are needed to ascertain the relationship between exchangeable sodium, exchangeable sodium percentage and base saturation percent in these soils.

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