Journal of Agricultural Science and Practice
Volume 9(4), pages 99-115, August 2024
Article Number: 4554E58F4
ISSN: 2536-7072
https://doi.org/10.31248/JASP2024.477
https://integrityresjournals.org/journal/JASP

Full Length Research

Assessment of nutrient status, macro faunal diversity and microbial isolates in date palm plantation in Damaturu Yobe State, Nigeria

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Received 8th July 2024; Accepted 5th August 2024

ABSTRACT: This research assessed nutrient status, macro-faunal diversity and microbial isolates in the soil of date palm plantation in Mai Sandari Damaturu, Yobe State. Parameters evaluated include; data on nutrient status of soils, assemblage and diversity of soil macro invertebrates and assemblage of microbial isolates based on growth performances of the date palm. The plantation was divided according to growth variabilities. Eighteen (18) auger points were taken, six (6) in each performance site based on the corresponding variability as observed. Soil samples were collected within same points for physicochemical analysis, microbial isolates and for soil macro-invertebrates 'identification and enumeration. One-way Analysis of Variance (ANOVA) was used to compare results of nutrient status of soils and to test for significant differences in nutrient concentration of the soils samples, mean separation was done using Least Significant Difference (LSD). Soil macro-invertebrate assemblage was analyzed for diversity indices of species using relevant formulae. Nutrient agar medium at 10^5 dilutions inoculated in a petri-dishes and incubated at 30±10°C for 2-5 days for bacteria colonies, while for fungi and actinomycetes, sabaurond dextrose agar was used at 25°C for 5-7 days and afterward microorganisms per colony forming units (Cfu) were counted. Analysis of variance for the soil parameters tested at $p \leq 0.05$ level of significance showed no significant differences in all the parameters of soil physical properties based on growth performance sites. However, organic carbon, organic matter and TN vary significantly after the post-hoc tests across growth performance sites in chemical properties ($p \leq 0.05$). Results showed a total of 2646 macro fauna scattered within the study area. Eleven (11) families of macro fauna were also identified in the study. Results from the study area showed that the area is highly rich in microorganisms. A total of 5096 colonies were scattered within 10 families in the study area. The finding of this study revealed that there was no significant difference among the physical properties across the study site leading to the conclusion that soil physical properties may not have been responsible for the observed differences in the growth of the Date Palm Plantation. A different pattern was however observed in the values of the chemical properties of the plantation where significant differences exist in organic carbon, organic matter and total nitrogen across these sites. Based on the findings of the study it is recommended that all application of agrochemicals except fertilizers in the plantation should be suspended until evidence of their efficiency on the palm trees is shown.

Keywords: Date palm, macro fauna, microorganism, physicochemical, soil, variability.

INTRODUCTION

Date palm plantations require careful attention to soil nutrients to ensure optimal growth and productivity. The soil in this region, like many arid areas, may have specific deficiencies that need to be addressed to support healthy

date palm growth (Gujja *et al*., 2022). The key soil nutrients and their management in date palm plantations include, Nitrogen (N), Phosphorus (P) Potassium (K) Calcium (Ca) and Magnesium (Mg) (Getachew, *et al.,* 2018). Nitrogen is crucial for vegetative growth and overall plant development. In sandy soils prevalent in arid regions, nitrogen tends to leach quickly, necessitating regular supplementation. Application of nitrogen-rich fertilizers or organic matter can help maintain optimal nitrogen levels in the soil (Arifin *et al.,*2014). Phosphorus is essential for root development, flowering, and fruiting in date palms Soils may be deficient in phosphorus, so regular application of phosphorus fertilizers is essential, especially during the establishment phase and early growth stages, Potassium is vital for overall plant health, stress tolerance, and fruit quality Harold *et al.,* (2020). Sandy soils often lack potassium, requiring supplementation through fertilizers like potassium chloride or potassium sulfate Adequate potassium levels promote strong root systems and help date palms withstand environmental stresses common in arid regions (Umeri *et al*., 2017a). Calcium and magnesium are secondary nutrients important for cell structure, enzyme activation, and nutrient uptake Soil testing can determine if calcium and magnesium levels are sufficient or if supplementation is needed through lime or dolomite applications (Wardle, 2006; Unanaonwi, 2009).
plantation soils in comparison to other soils are characterized by the presence of litter with an associated unique micro flora and fauna (Lucas-Borja *et al.,* 2020), higher porosity, higher permeability, more stable soil aggregates and greater water holding capacity (Rahman *et al.,* 2012). The carbon-nitrogen ratio is generally wide and decreases as decomposition occurs in forest soils, whereas in other soils, this ratio is usually much lower (Kekane *et al.,* 2015). Trees may play a major role in increasing soil fertility through the ecological and physicochemical changes they induce in soil (Umeri *et al.,* 2017b). Litter fall is the main path for the return of dead organic matter and nutrients to the soil and humus formation in tropical forest systems (Osman, 2012). Soil physical properties have long been considered to exert great influence on the distribution, growth and development of trees. Tree cover, in turn, influences the improvement of the physical properties of soil (Masomeh and Hashem, 2016).

Soil characteristics are made up of two properties namely physical and chemical and soil will usually behave according to the proportion and organization of these properties. More so, the proportion and percentage of the chemical and physical properties of a soil determines the use a soil is put into. Soils are made up of four basic components: minerals, air, water, and organic matter. In most soils, minerals represent around 45% of the total volume, water and air about 25% each, and from 2% to 5% organic matter (Retallack, 2008a). The mineral portion consists of three distinct particle sizes classified as sand, silt, or clay (Getachew, *et al.,* 2018). Sand is the largest particle that can be considered soil. Sand is largely quartz, though other minerals are also present. Quartz contains no plant nutrients, and sand cannot hold nutrients as it is easily leached by rainfall or irrigation. Silt particles are much smaller than sand, but like sand, silt is primarily quartz (Unanaonwi, 2015). The smallest of all soil particles is clay. Clays are quite different from sand or silt, and most types of clay contain appreciable amounts of plant nutrients. Clay has a large surface area resulting from the plate-like shape of the individual particles. Sandy soils are less productive than silts, while soils containing clay are the most productive and use fertilizers most effectively (Unanaonwi, 2015). Although farmers, ranchers, foresters, micro-biologists, etc. think of soil differently for different purposes, understanding soils and managing them well is essential to human welfare (Lucas-Borja *et al.,* 2020).

Macro fauna is the most conspicuous group of organisms which have great potential to modify the soil environment through their activities. Earthworms and termites are widely recognized for their role in soil structure formation, organic matter incorporation and decomposition and nutrient mineralization. Adriano *et al.* (2020) consider these organisms as “ecosystem engineers’’, which are defined as organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials; in so doing they modify, maintain and create habitats. Earthworms and termites ingest organic matter or a mixture of mineral soil and organic matter and create channels and nests in the soil, thus creating solid organo-mineral structures that may persist longer than the organisms that produced them. They developed highly efficient digestion systems based on internal mutualism with micro flora and protozoa that live in their gut. Earthworms and termites constitute >90% of the biomass of the invertebrate fauna in soils of sub-Saharan Africa (Adriano *et al.,* 2020).

Soil contains many micro and macro flora and fauna as long as there is a carbon source for energy. A large number of bacteria in the soil exist, but because of their small size, they have a smaller biomass. Actinomycetes are 10 times smaller in number but are larger in size so they are similar in biomass to bacteria in soil (Bhattarai *et al*., 2015; Masomeh and Hashem, 2016).

Soil microbes, bacteria, archaea, and fungi play diverse and often critical roles in these ecosystem services. The vast metabolic diversity of soil microbes means their activities drive or contribute to the cycling of all major elements (e.g. C, N, P), and this cycling affects the structure and the functions of soil ecosystems as well as the ability of soils to provide services to people provisioning and regulating ecosystem services (Aislabie *et al.,* 2013). Plant and animal detritus and root exudates represent essential sources of energy and nutrients for soil microbial and faunal communities. Bacteria and fungi represent 95% of the biomass present in most soils, where they interact with a combination of micro-fauna (nematodes, protozoa), Meso-fauna (acari, Collembola, mites) and macro-fauna (earthworms, termites, molluscs)

in complex soil food-web systems that determine the turnover of organic matter and associated nutrients in the soil environment (Durán *et al.,* 2019, Moghimian and Kooch, 2013).

The decomposition of organic carbon in soil is driven primarily by the activities of bacteria and fungi, while only 10–15% of soil carbon flux can be directly attributed to the actions of fauna (Gujja *et al.,* 2023, Scholten *et al.,* 2017). The vast majority of soil microorganisms are heterotrophs that rely on organic matter for energy and nutrients. These can be divided into microorganisms that respond primarily to the addition of fresh carbon substrates (zymogenous or *r*-selected biomass) and those that derive their energy mainly from the decomposition of older, more recalcitrant forms of organic carbon (autochthonous or *K*-selected biomass) (Gujja *et al.,* 2023; Scholten *et al.,* 2017).

In the fifteen (15) years of the establishment of the Date Palm Plantation in Damaturu Local Government Area of Yobe State, studies have not been done on the physicochemical and biological constituents of the soil. The growth of the individual date palm plants has not been uniform, while some are performing very well, others indicate stunted growth. Since the growth of every plant depends on the soil nutrient which is in turn affected by the activities of soil macro and micro fauna, the information on the soil components in the date palm plantation becomes a pre-requisite to understanding the differences in the performances of individual date palm.

Therefore, this study aims to assess the nutrient status, macro faunal diversity and microbial isolates in the study area. The specific objectives are to:

1. Examine the soil nutrient status of the plantation,
2. Identify and evaluate the macro faunal diversity in the study area.
3. Identify and evaluate the microbial isolates in the study area.

At the end of the study, the nutrient status of the date palm plantation would have been ascertained. The information on macro and micro fauna diversity will thus provide a baseline information for future management of the date palm plantation and by extension any other date palm plantation that may be grown under similar conditions. The results of the research will be an invaluable tool to the date palm plantation managers in the Department of Forestry Technology and Management, of Yobe State College of Agriculture, Science and Technology Gujba and indeed many other organizations and individuals that are involved in date palm research and production. The study was limited to the investigation of physical, chemical and biological components of the soil of the study area.

MATERIALS AND METHODS

The study area

Yobe State is located in the northeastern part of Nigeria. It lies between latitude 12 and 22°N of the equator and longitude 11 and 42°E of the Greenwich meridian. It shares boundaries with Gombe State in the South and West Bauchi State, in its Northwest jigawa state, and in the east Borno State, it has an international boundary with the Niger Republic. The total land area of Yobe is 4,660,900 ha (46,609 km^2) from which 386,710 ha constitute the area covered by forest reserves. Moreover, the total population in Yobe is 2,321,339. It is divided into 17 Local Government Areas (Figures and 1) (Bukar and Abba, 2022; Tukur, 2013). Yobe State falls under the Sudan, savannah type of vegetation, and it experiences distinct dry and wet seasons with temperature and humidity varying with seasons. The wet or rainy season falls between May and October, which is characterized by a single maximum in August and September. During this season, the moisture-laden southwest trade wind from the Atlantic Ocean blows over the area. Seventy per cent of the total rainfall in the area happens to fall within four months from May to September (Tukur, 2013), blows area has an average of 62 rainy days, while the average amount of rainfall recorded in the area is 972 mm. The harmattan period was between December to March, and this period was characterized by dry, dusty and hazy northern trade wind that blew over the area from the Sahara Desert. The temperature within the area varies with season. Although the temperatures are relatively high almost all year round, the temperature of the area ranges from 27 to 34°C. December and January are the coldest months with an average temperature of 28°C (Bukar and Abba, 2022; Tukur, 2013). The natural vegetation of the area is Sudan savannah and Sahel type which is characterized by scattered vegetation. The vegetation has a wide variety of savannah tree species among which area are; *Acacia spp, Adansonia spp, Anogeissus spp*. (Bukar and Abba, 2022; Tukur, 2013).

Rainfall and relative humidity

The mean annual rainfall pattern in the state shows that the amounts range from 400 mm in the north-south part to 1600 mm in the southern part. Generally, mean annual rainfall is less than 1200 mm in the Damaturu and east–western parts of the state including Fune, Potiskum, Fika and Nangere Local Government Areas. On the other hand, the north-south strip and the southern part have over 1800 mm. The mean length of the rainy season is about 120 days in the state.

The lowest relative humidity in the state (20 – 30%) is recorded between December and February. It starts increasing as from April and reaches its peak (about 80%) in August and September. This is due to the influence of the humid maritime air mass which covers the whole state during this period. Relative humidity starts to decline again in October following the cessation of rains. In general, there is a north-south increase in relative humidity values in the state (Bukar and Abba, 2022; Tukur, 2013).

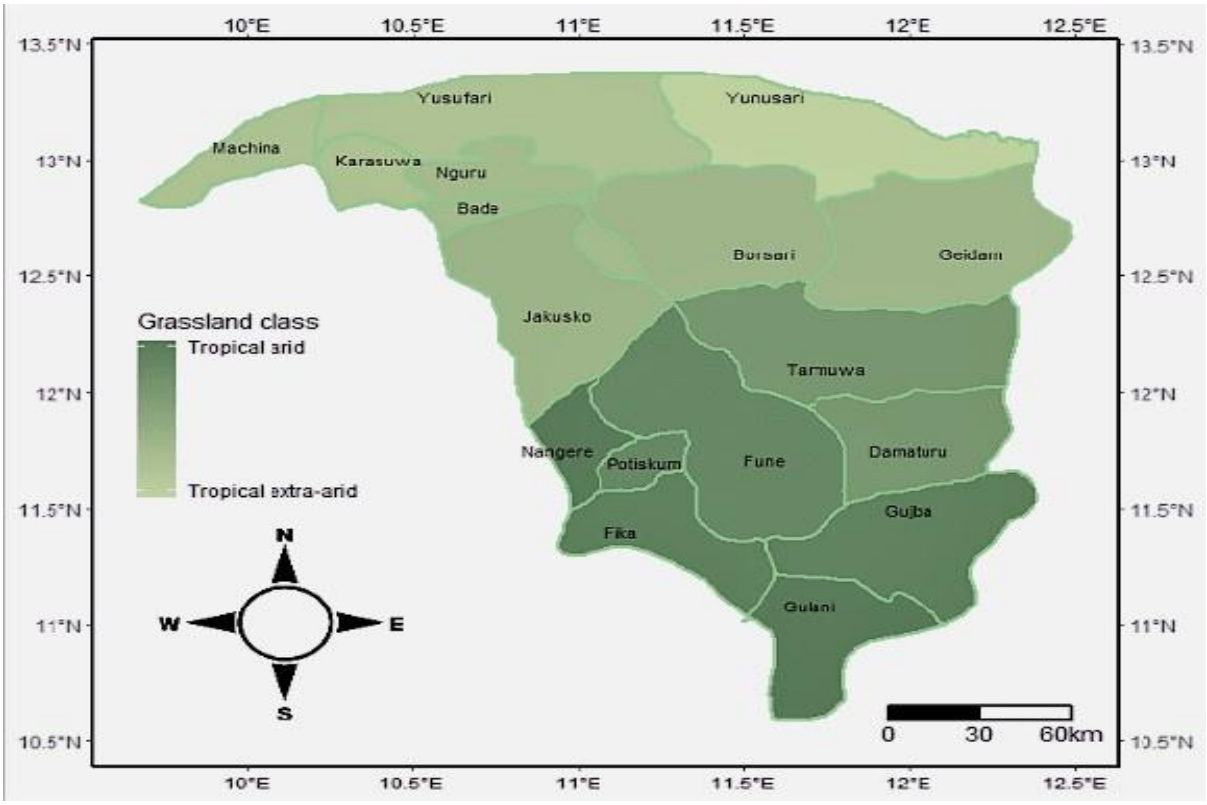

Figure 1. Map of Yobe State Nigeria (Source: GIS Laboratory, Geography Department Yobe State University, Damaturu (2024).

Temperature

An air temperature characteristic in Yobe State is typical of the West African Savannah climate. Temperature in this climatic region is high throughout the year because of high radiation income which is relatively evenly distributed throughout the year. However, there is usually a seasonal temperature change. There is a gradual increase in temperature from March to May. There is a distinct drop in temperature at the onset of rains due to the effect of cloudiness.

Maximum temperature in the state can reach 40°C, particularly in April while minimum temperature can be as low as 18°C between December and January. The mean monthly temperature in the state ranges from 16 to 23°C (Tukur, 2013).

Sampling design and data collection

A soil survey conducted at the date palm plantation revealed variability in the growth of the date palm trees. Therefore, the plantation was divided into three areas according to these variabilities (high, medium and low growth). Six auger points were made and soil samples were collected from surface and subsurface layers in each of the areas (0-15 cm and 16-30 cm). These were appropriately labelled in polythene bags and taken to the soil science laboratory of Yobe State University for analysis of physicochemical properties.

Physical properties

Particle size analysis

The particle size analysis was determined by the Bouyoucos hydrometer method described by Gee and Bauder (1986). Fifty (50) grams of the soil was shaken with 50 ml of 5% Calgon (Sodium hexametaphosphate) for 30 minutes for proper and complete dispersion. The suspension was then transferred into a 1000 ml graduated cylinder and made to volume with distilled water. Hydrometer readings were taken at 40 seconds and 2 hours. A blank containing no soil was carried out through the same procedure to correct the reading that was taken in the soil suspension.

Bulk densities

Core samples were used to determine the bulk density in the laboratory using the procedure described by Blake and Hartge (1986) by oven dry the samples were mix to give five homogenous samples for each area of variability, and drying the soil sample to a constant weight at 105°C and dividing the dry weight of the soil by the total volume of the sphere.

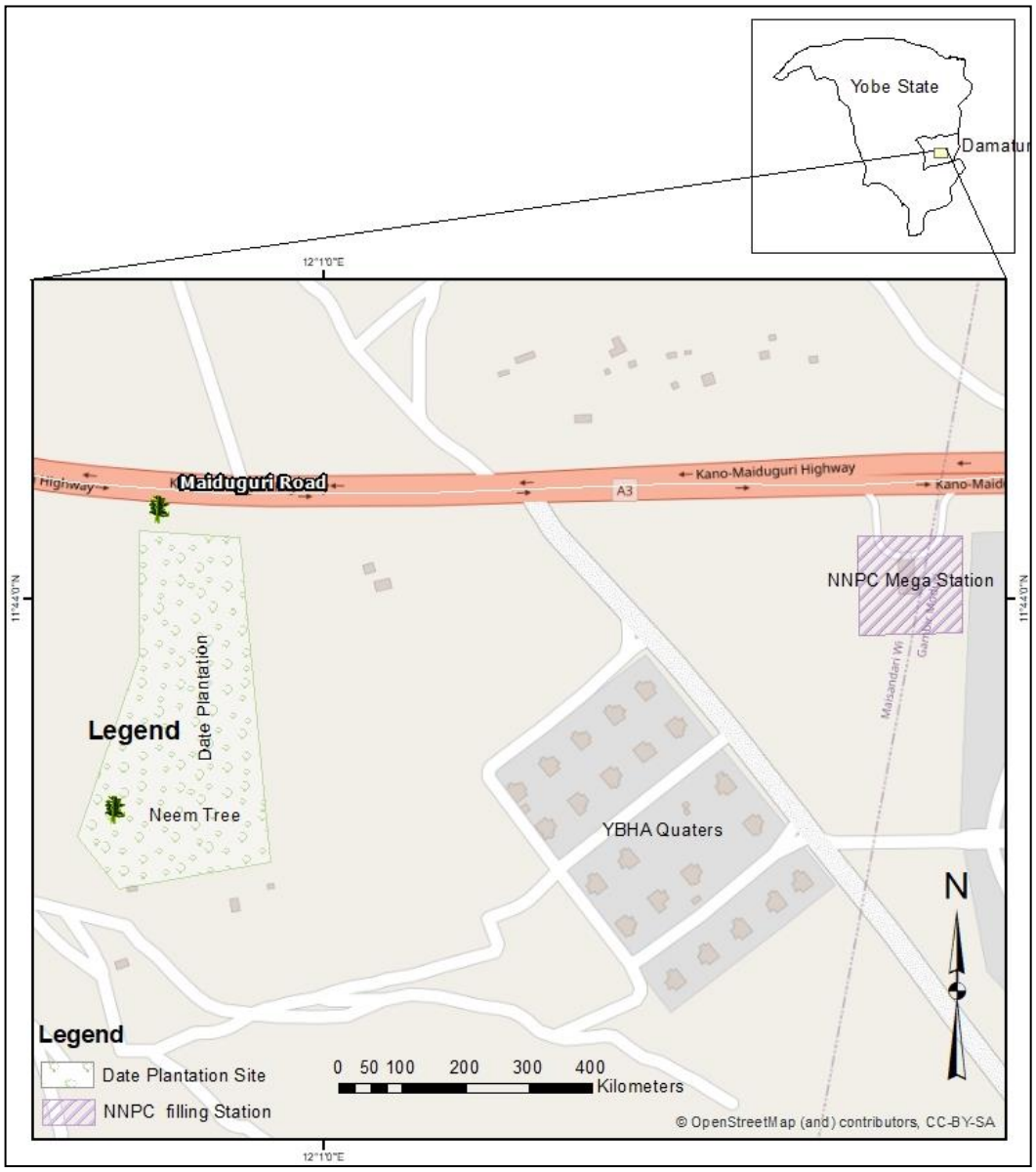

Figure 2. Map of Damaturu, showing the study area (Source: GIS Laboratory, Geography Department Yobe State University, Damaturu, 2024).

$$\text{Bulk density } (\text{g}/cm^3) = \frac{\text{weight of oven dry soil}}{\text{volume of soil } (cm^3)}$$

Particle density

This was determined after the removal of entrapped air in soils using the pycnometer method as described by Blake and Hartge (1986). Forty grams of oven-dried soil was weighed into a pycnometer and filled to the brim with boiled and cooled water.

Total porosity

Total porosity was calculated mathematically from the results of bulk density and particle density (Agbenin and Tiessen, 1995) using the formula:

$$\text{Tp} = 100\text{-} \left(\left(\frac{\rho b}{\rho p} \right) * 100 \right)$$

Water holding capacity (WHC)

The soil water holding capacity analysis was carried out using the core sample method. The results obtained were substituted by this expression

$$\text{W. H. C} = \frac{W3 - W2}{W4 - W1}\, x100$$

Where: W_1 = covered the bottom of the milk can with the filter paper and weigh it on the balance, W_2 = gently field a dry soil into the milk can and weigh again, W_3 = place the filled can on a petric dish and add water to the side of the milk can until water depth is 6 mm and leave it to stand overnight and carefully remove the can and weigh again, W4 = Place the can in an oven at a temperature of 105°C for 24 hours and remove to cool down and weigh again (Agbenin and Tiessen, 1995).

Chemical properties

Soil reaction (pH)

pH was determined in both water solutions at a 1:2 soil/water or solution ratio (Agbenin and Tiessen, 1995). Twenty (20) ml of distilled water was added to ten (10) grams of soil samples and stirred. The pH of the suspension was read with a pH meter after 30 minutes.

Electrical conductivity (EC)

The electrical conductivity of the soil saturation extract was determined at a 1:2 soil/water ratio (Udo *et al.,* 2009). Ten (10) grams of the soil samples was soaked with 20 ml of distilled water for 1 hour. The suspension was then read using a Wheatstone bridge at 25°C.

Organic carbon

Organic carbon contents of the soil samples were determined using dichromate wet oxidation method of Walkley-Black as described by Black (1965).

Organic matter (%)

Value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 (Black, 1965).

Total nitrogen (TN)

Total nitrogen was determined by the micro Kjeldahl technique (Harold *et al.,* 2020). One (1) gram of soil was digested with 10 ml of concentrated sulphuric acid; the digested was then diluted with 100 ml of distilled water. 10 ml of the aliquot was distilled with sodium hydroxide. The distillate was then titrated with 0.01N H_2SO_4 to a pink endpoint.

Available phosphorus (AVP)

Available phosphorus was determined following the procedure described by IITA (1979) using the Bray-1 extraction method (Bray and Kurtz, 1945). Available phosphorus was extracted from Ten (10) grams of soil using ammonia fluoride in hydrochloric acid. Phosphorus in solution was then determined calorimetrically by the modified single solution procedure using ascorbic acid (Koralage *et al.,* 2015).

Exchangeable cations

Exchangeable cations (Ca, Mg, K and Na) were determined using the NH_4OAc saturation method at pH 7.0 as described by Thomas (1982). Ten (5) grams of soil samples were leached with NH_4OAc solution. Potassium and Sodium were read from the flame photometer, while Calcium and Magnesium in the solution were determined using the titrimetric method.

Total exchangeable acidity

The soil samples were leached with 1M KCl solution. Total exchangeable acidity (H+Al) was determined by titration of the extract with standard NaOH solution (Thomas, 1982). The difference between total exchangeable acidity and exchangeable aluminium gives the amount of exchangeable hydrogen.

Effective cation exchange capacity (ECEC)

The effective cation exchange capacity was determined by summing up the exchangeable cations (Ca, Mg, K and Na) and the exchangeable acidity (H+Al) (IITA, 1979).

Base saturation (BS) percentage

The base saturation percentage was calculated for both CEC (NH_4OAc) and ECEC from the formula: (Agbenin and Tiessen, 1995).

$$\%BS = \frac{Total\ exchangeable\ bases}{CEC\ or\ ECEC} x100$$

Assessment of species of soil macro invertebrates

Assessment of macro fauna species was carried out using plots of 20 m × 20 m which were randomly selected from the assessment of micro fauna spp was done using plots of 1 m x 1 m that were laid at each anger point (Gujja *et al*., 2023; Dishan *et al*., 2018). Topsoil for biological assessment of soil samples was collected using trowels at depths ranging from 0-30 cm. The soil samples were immediately spread on a board of about 60 cm^2 and sorted for the presence of macro fauna (earthworms, crickets, termites, mites, centipedes, millipedes, ants, beetles etc.).

The soil macro invertebrates encountered in each of the sites were counted and recorded. Identification was done using literature. Pictures of unidentified soil macro invertebrates were taken for the purpose of identification. The computation of species diversity indices per study site was done.

Soil sampling process for microbial isolates

The soil sample was taken at each auger point in the date palm plantation. A composite sample, after mixing the sample thoroughly, sterile polythene bags were used to convey samples to the laboratory within 24 hours of collection for analysis of soil bacteria, fungi and actinomycetes at the Department of Microbiology of Yobe State University, Damaturu.

Culture

The bacteria population was estimated by the method of Vieira and Nahas (2005) using the nutrient agar medium at 10^5 dilutions. The inoculated Petri dishes were incubated at 30±10°C for 2-5 days for bacteria colonies. The laboratory analysis involved adding 1 g of soil into 9 ml of sterile water in a test tube, followed by vigorous shaking, and then serial dilution was done in four test tubes before transfer into the Petri dish. However, molten agar/media was poured into the petri dish.

For the isolation and characterizing of fungi and actinomycetes dilution plate method was used, sabouraud dextrose agar for fungi and actinomycetes selected media for actinomycetes was used as basal medium to isolate species. The inoculated Petri dishes were incubated at 25°C for 5-7 days to grow the fungi and actinomycetes colonies. Representative isolates of fungi were identified under the microscope with the help of standard manuals (Naher *et al.,* 2013). Representative isolates of bacteria were also identified under the microscope. Fungi identification was done under the appearance and pigmentation of spores on agar and actinomycetes were identified under the appearance on agar plates.

Data analysis

Frequency tables were used in presenting the list of micro and macro species.

$$\text{Frequency} = \frac{No.of\ individual\ specie\ occurrence}{Total\ number\ of\ all\ species} x100$$

Data on macro faunal diversity was determined using Shannon Diversity Index: This is illustrated as follows:

$H^1 = -\sum_{i-1}^{s} PiIn(Pi)$ (Yager *et al.,* 2017)

Where: H^1 = Shannon Diversity Index; n_i = number of individuals in species; N = total number of all individuals; Pi = relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: n_i/N, and In = natural logarithm.

One-way analyses of variance (ANOVA) was used to compare the different chemical and physical properties of soil nutrients based on location and depth using SPSS Version 17. The statistical model used was as follows:

$Yij = \mu + Ti + eij$

Where: μ = the overall mean; Y_{ij} = the j^{th} observations; T_i = the observations in each

Mean separation was done using the Duncan Multiple Range Test ($p < 0.05$).

RESULTS

Soil physicochemical properties in the study sites

Soil physical properties of the study sites

The results of texture classes of soils in high-performance sites of Date Palm Plantation indicated a variation in textural forms from sandy clay loam, sandy loam and loamy sand (Table 1). The percentage ranges of sand, silt and clay of the whole stretch were found to be from 72.4 to 80.4%, 7.8 to 14.3% and 14.3 to 20.8%, respectively. The bulk density of the soil had values ranging from 1.46 to 1.54 g/cm^3. The total percentage porosity recorded ranged from 40 to 42.5% in all the soils. Water holding capacity was between 9.6 and 11.2% (Table 1).

The result of texture classes of soils in the medium performance site of the plantation also indicated a variation in textural forms from sandy loam and sandy clay loam (Table 2). The percentage ranges of sand, silt and clay of the portion were found to be from 69.4 to 78.4%, 5.30 to 8.30% and 14.3 to 25.3%, respectively. The bulk and particle density of the soil had a range of values from 1.46 to 1.53 g/cm^3 and 2.53 to 2.75 g/cm^3, respectively. The total percentage porosity ranged from 40.0 to 42.5% and water holding capacity was between 9.6 and 11.20% (Table 1).

The results of texture classes of soils in the low-performance site of the study area indicated a variation in textural forms from sandy clay loam, sandy loam and loamy sand (Table 1). The percentage ranges of sand, silt and clay in the area were found to be from 27 to 33.3%, 11 to 28% and 14 to 32%, respectively. The bulk and particle density of the soil had a range of values from 1.36 to 1.4 8g/cm^3 and 2.43 to 2.64 g/cm^3, respectively. The total percentage porosity ranged from 31 to 50% in all the plantations of soils. Water holding capacity was between 9.3 and 11.5% (Table 1).

Table 1. Soil pH physical properties of growth site in the study area.

Growth site	Location	Sand (%)	Silt (%)	Clay (%)	Texture classes	B. D (gcm^3)	P. D (gcm^3)	T. P (%)	WHC (%)
High	P1	75.40	10.80	13.80	Sandy loam	1.53	2.55	40.00	10.40
	P2	71.40	7.80	20.80	Sandy loam, sandy clay	1.46	2.54	42.50	9.60
	P3	80.40	4.80	14.80	Loam	1.53	2.56	42.50	9.75
	P4	73.40	7.80	18.80	Sandy loam	1.48	2.61	42.00	9.70
	P5	71.40	14.30	14.30	Loamy sand	1.54	2.73	41.50	10.35
	P6	72.40	10.00	16.80	Sandy loam	1.51	2.61	41.50	11.20
Medium	P1	69.40	5.30	25.30	Sandy loam	1.47	2.56	40.00	10.40
	P2	78.40	6.30	15.30	Sandy loam, sandy clay	1.53	2.64	42.50	9.60
	P3	70.40	8.30	21.30	Sandy loam	1.46	2.53	42.50	9.75
	P4	76.40	8.30	14.30	Sandy loam	1.53	2.59	42.00	9.70
	P5	72.40	8.30	18.30	Loamy sand	1.48	2.53	42.00	10.35
	P6	73.40	7.30	19.30	Sandy loam	1.48	2.75	41.50	11.20
Low	P1	33.2	16	30.8	Sandy loam	1.48	2.56	41	10.2
	P2	35	18	18.8	Sandy loam	1.38	2.56	31	9.2
	P3	39	12	26	Sandy clay loam	1.36	2.62	40	11.2
	P4	55	28	20	Loamy Sand	1.41	2.69	39	9.5
	P5	41.2	22	14	Sandy clay loam	1.31	2.58	45	11.3
	P6	27	11	32	Clay loam	1.41	2.43	50	11.5

Key: B. D = Bulk density g/cm³, T. P = T /porosity%.

Table 2. Mean separation of physical properties of soils according to variability.

Sites	Sand (%)	Silt (%)	Clay (%)	B.D (g/cm^3)	PD (%)	T. Porosity (%)	WHC (%)
Low	38.4^a	17.83^a	23.6^a	1.35^a	2.57^a	41.00^a	10.48^a
Medium	75.00^a	9.60^a	14.40^a	1.53^a	2.61^a	41.60^a	10.46^a
High	76.60^a	7.20^a	17.20^a	1.50^a	2.60^a	42.20^a	10.00^a

Means with different letters(s) along the column are significantly different ($p \leq 0.05$) (**Source:** Field Experiment, 2024).

Analysis of variances (ANOVA) of soil physical properties based on the variability of the plants according to the growth performance of the plants revealed that there was no significant difference in values of the soil properties ($p \geq 0.05$) (Table 2).

Soil chemical properties in the study sites

Table 3 shows the values of some soil chemical properties of the high-performance site of the Date Palm Plantation. The results indicate that the pH values ranged from 5.70 to 6.69, electrical conductivity values were between 0.27 to 0.83 μs/cm, and organic carbon and organic matter content values ranged from 0.73 to 1.02% and 1.27 to 1.75%, respectively. Total nitrogen content values ranged from 0.13 to 0.18% while available phosphorous ranged from 0.84 to 10.93 mg/kg. The exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+) had their ranges from 3.12 to 4.67 cmol/kg, 1.56 to 2.68 cmol/kg, 0.41 to 0.76 cmol/kg and 0.46 to 0.76 cmol/kg, respectively. The mean values of TEB and TEA ranged from 6.85 to 7.99 Cmol/Kg and 2.25 to 7.87 cmol/kg, respectively. The mean values of ECEC ranged from 9.73 to 11.39 Cmol/Kg. Percentage base saturation and ESP had values between 68.99 and 77.72% and 4.90 to 7.66% respectively.

Table 3 shows the mean values of some soil chemical properties as they occurred in the medium performance date palm in the study area. The results indicate that the pH values ranged from 5.70 to 6.50. Electrical conductivity values were between 0.18 to 0.60 μs/cm, and organic carbon and organic matter content values ranged from 0.5% to 0.71% and 0.88 to 1.22%, respectively. Total nitrogen content values ranged from 0.07 to 0.12% while available phosphorous ranged from 8.34 to 10.92 mg/kg. The exchangeable bases, (Ca^{2+}, Mg^{2+}, Na^+ and K^+) had their ranges from 3.12 to 5.31 cmol/kg, 1.28 to 2.26 cmol/kg, 0.54 to 0.68 cmol/kg and 0.41 to 0.72 cmol/kg, respectively. The mean values of TEB and TEA ranged from 6.85 to 7.25 cmol/Kg and 2.10 to 3.25 cmol/kg respectively. The mean values of ECEC ranged from 9.25 to 12.07 cmol/Kg. Percentage base saturation and ESP had values between 70.405 to 79.864% and 4.151 to 7.782% respectively.

Table 3. Soil chemical properties of High Growth performance Site of the study area.

Growth site	Loc.	Ph	EC (μs/cm)	Org. C (%)	Org. M (%)	TN (%)	AvP (mg/kg)	Ca Cmol/kg	Mg Cmol/kg	Na Cmol/kg	K Cmol/kg	TEB Cmol/kg	TEA Cmol/kg	ECEC Cmol/kg	PBS (%)	ESP (%)
High	P1	6.22	0.48	1.02	1.75	0.18	0.84	3.37	2.54	0.56	0.47	6.93	2.80	9.73	70.88	6.05
	[2	6.41	0.32	0.86	1.49	0.15	9.52	4.67	2.22	0.41	0.69	7.99	2.40	10.39	76.49	4.04
	P3	5.95	0.27	0.82	1.41	0.14	10.06	4.55	2.28	0.59	0.46	7.87	2.25	10.12	77.72	5.84
	P4	5.70	0.83	0.81	1.39	0.14	9.30	3.68	2.68	0.57	0.77	7.65	3.45	11.39	68.99	5.08
	P5	6.00	0.28	0.77	1.33	0.13	10.81	3.12	2.48	0.76	0.49	6.85	3.00	9.95	69.74	7.66
	P6	6.69	0.37	0.73	1.25	0.13	10.92	4.46	1.56	0.46	0.65	7.15	2.60	9.75	73.34	4.90
Medium	P1	6.40	0.37	0.71	1.22	0.12	9.63	4.08	2.08	0.67	0.41	7.25	2.10	9.35	9.73	4.87
	p2	6.35	0.38	0.69	1.19	0.12	10.92	4.33	1.60	0.54	0.69	7.16	2.95	10.13	10.27	7.31
	P3	5.95	0.23	0.67	1.15	0.11	9.73	5.31	2.20	0.59	0.72	8.82	3.25	12.07	9.69	6.19
	P4	5.70	0.60	0.55	0.95	0.09	9.88	3.12	2.26	0.68	0.65	6.85	2.40	9.25	8.81	5.48
	P5	6.26	0.18	0.53	0.92	0.09	8.81	3.79	2.03	0.61	0.50	7.02	2.73	9.82	11.45	6.18
	P6	6.50	0.32	0.51	0.88	0.07	8.34	3.99	1.28	0.54	0.55	7.23	3.20	11.70	11.13	9.35
Low	P1	6.86	0.43	0.61	1.05	0.12	9.73	5.31	2.20	0.72	0.59	8.82	3.25	12.07	8.34	7.06
	p2	6.35	0.23	0.69	1.19	0.12	10.72	4.33	1.28	0.36	0.92	7.33	2.95	10.53	10.27	8.23
	P3	5.95	0.60	0.67	1.15	0.11	9.73	5.31	2.40	0.55	0.72	8.60	3.00	10.28	9.88	6.19
	P4	5.70	0.27	0.55	0.95	0.09	9.88	3.12	2.26	0.63	0.67	6.85	2.40	9.25	8.81	5.48
	P5	6.15	0.18	0.53	0.92	0.09	8.81	3.79	2.03	0.81	0.54	7.02	2.73	9.82	11.45	6.18
	P6	6.51	0.39	0.51	0.88	0.07	8.34	4.12	1.28	0.50	0.55	7.23	3.10	11.70	11.13	9.35

Key: Loc. = Location, pH = Soil reaction, EC = Electrical conductivity, OC = Organic carbon, OM=Organic matter, TN =Total nitrogen, Av-p = Available phosphorus, Na = Sodium, Ca = Calcium, Mg = Magnesium, K = Potassium, TEA = Total exchangeable acidity, TEB = Total exchangeable base, ECEC = Effective cation exchange capacity, PBS = Pacentage Base saturation (Source: Field Experiment, 2024).

Table 3 shows the mean values of some soil chemical properties of low performance site of the study area. The results indicate that the pH values ranged from 5.70 to 6.86, electrical conductivity values were between 0.18 to 0.60μs/cm, while organic carbon and organic matter content values ranged from 0.51 to 0.69% and 0.88 to 1.19%, respectively. Total nitrogen content values ranged from 0.07 to 0.12% while available phosphorous ranged from 8.34 to 10.73 mg/kg. The exchangeable bases, Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} had their range from 3.12 to 4.33 cmol/kg, 1.28 to 2.40 cmol/kg, 0.50 to 0.72 cmol/kg and 0.54 to 0.92 cmol/kg, respectively. The mean values of TEB and TEA ranged from 6.85 to 8.82 cmol/Kg and 2.40 to 3.25 cmol/kg, respectively. The mean values of ECEC ranged from 9.25 to 12.07 cmol/Kg. Percentage base saturation and ESP had values between 8.34 to 11.45% and 6.18 to 9.35%, respectively.

Analysis of Variance (ANOVA) of p≤0.05 of the soil chemical properties of all the sites showed that there were significant differences in organic carbon, organic matter and TN, while others were not significantly different (Table 4).

Diversity of macro invertebrate species in the study areas

Table 5 shows a checklist of macro-invertebrate species diversity in the study area. A total of 1379, 785 and 437 individual species belonging to 11, 9 and 7 Taxa, respectively from the studied sites. Species encountered included; Earthworm (*Lumbricina terrestris*), Ant (*Monomorium minimum*), Subterranean termite (*Heterotermes species*), Millipede (*Eurymerodesmidae spp*), Giant centipede (*Scolopendra gigantea*), Crickets

Table 4. Mean separation of chemical properties of soil according to variability.

Growth site	pH (1:2)	EC (dS/m)	Org. C (%)	Org. M (%)	TN (%)	AvP (mg/kg)	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	K (cmol/kg)	TEB (cmol/kg)	TEA (cmol/kg)	ECEC (cmol/kg)	PBS (%)	ESP (%)
Lower	6.25[a]	0.35[a]	0.59[b]	1.02[b]	0.1[b]	9.53[a]	4.33[a]	1.91[a]	0.60[a]	0.67[a]	7.64[a]	2.91[a]	10.61[a]	9.98[a]	7.08[a]
Medium	6.19[a]	1.81[a]	0.52[a]	1.05[a]	0.1[a]	9.55a	4.10[a]	0.91[a]	0.61[a]	0.59[a]	7.38[a]	2.77[a]	10.39[a]	10.18[a]	6.56[a]
High	6.16[a]	0.43[a]	0.83[c]	1.44[c]	0.15[c]	8.58[a]	3.98[a]	2.93a	0.56[a]	0.58[a]	7.41[a]	2.75[a]	10.22[a]	72.86[a]	29.48[a]

Means with different letters(s) along the column are significantly different ($p \leq 0.05$). **Key:** pH = Soil reaction, EC = Electrical conductivity, OC = Organic carbon, OM=Organic matter, TN =Total nitrogen, Av-p = Available phosphorus, Na = Sodium, Ca = Calcium, Mg = Magnesium, K = Potassium, TEA = Total exchangeable acidity, TEB = Total exchangeable base, ECEC = Effective cation exchange capacity, PBS = Pacentage Base saturation (**Source:** Field Experiment, 2024).

Table 5. Checklist of macro fauna in the study area.

S/No.	Family name	Scientific name	English name
1	Acrididae	*Caelifera*	Grasshopper
2	Achipteriidae	*Trombidium holosericeum*	Soil mite
3	Formicidae	*Formicide species*	Ant
4	Glomeridae	*Glomeris marginata*	Millipede
5	Gryllidae	*Gryllus assimillis*	Cricket
6	Lithobiidae	*Lithbius variegatus*	Centipede
7	Lumbricidae	*Lumbricus terrestris*	Earthworm
8	Noctuidae	*Spodoptera ornithogalli*	Armyworm
9	Pentatomidae	*Acrosternum hilare*	Stink Bug
10	Rhinotermitidae	*Heterotermes species*	Subterranean termite
11	Stephylinidae	*Bisnius blandus*	Rove beetle

Source: Field Experiment, (2024).

(*Gryllus assimillis*), Ground beetle (*Scaritinae clivinini*), Brown marmorated stink bug (*Halyomorpha halys*), and common centipede (*Scutigera coleoptrata)*.

Shannon wiener Diversity Index, individual, evenness and equitability indices values of macro-invertebrate species for the studied sites are presented in Table 10. The values followed the order; individual 365 > 139 > 153, Shannon wiener Diversity Index 1.252 > 1.823 > 1.838, Evenness values 0.2499 > 0.4763 > 0.6283, Equitability indices 0.4745 > 0.7108 > 0.7983 and Berger parker,values were 0.7069 > 0.3885 > 0.281, respectively (Table 11).

Soil micro - organisms (cfu^{-1}) in the study areas

The soil microorganisms 'colony count result shows the presence of Actinomycetaceae, *(Actinomyces cream, Actinomyces yellow, Actinomyces blue),* Staphylococcaceae; *(Staphylococcus aurus),* Streptococcaceae, *(Streptococcus species),* Pseudomonadaceae, *(Pseudomonas auroginosa),* Enterobacteriaceae, *(Escherichia coli),* Bacillaceae, *(Bacillus subtilis),* Trichocomacaceae, *(Aspergillus niger, Aspergillus fumigates)*, Lactobacillaceae, *(Lactobacillus species),* Aeromonadaceae, *(Aeromonas species),* Streptomycetaceae, *(Strestomycetes species),* Enterobacteriaceae, *(Klebsiilla species, Proteus species, Citrobacter species),* and Bacillaceae, *(Bacillus copus)*. The soil microorganisms colony

Table 6. Some population of macro-fauna species of the study area according to variability.

S/No	Family name	Scientific name	English name	Low Shannon_H	Medium Shannon_H	High Shannon_H
1	Acrididae	*Caelifera*	Grasshopper	1.388	1.488	1.623
2	Achipteriidae	*Trombidium holosericeum*	Soil mite	1.248	1.692	1.908
3	Formicidae	*Formicide species*	Ant	1.794	2.067	2.201
4	Glomeridae	*Glomeris marginata*	Millipede	1.039	1.277	1.328
5	Gryllidae	*Gryllus assimillis*	Cricket	1.685	1.947	2.059
6	Lithobiidae	*Lithbius variegatus*	Centipede	0.959	1.163	1.197
7	Lumbricidae	*Lumbricus terrestris*	Earthworm	1.807	2.081	2.165
8	Noctuidae	*Spodoptera ornithogalli*	Armyworm	-	0.528	-
9	Pentatomidae	*Acrosternum hilare*	Stink Bug	1.201	1.539	1.719
10	Rhinotermitidae	*Heterotermes species*	Subterranean Termite	2.054	2.313	2.455
11	Stephylinidae	*Bisnius blandus*	Rove beetle	1.314	1.565	1.643

Source**:** Field Experiment, (2024).

Table 7. Diversity of macro fauna in the study area.

Parameter	High diversity level	Medium diversity level	Low diversity level
Taxa_S	11	9	7
Individuals	365	139	153
Shannon_H	1.252	1.823	1.838
Simpson_1-D	0.4887	0.765	0.8023
Evenness_e^H/S	0.2499	0.4763	0.6283
Brillouin	1.189	1.686	1.73
Menhinick	0.7328	1.103	0.8085
Margalef	2.203	2.432	1.789
Equitability_ J	0.4745	0.7108	0.7982
Fisher alpha	2.888	3.51	2.397
Berger-Parker	0.7068	0.3885	0.281

Source: Field Experiment, (2024).

were categorized into three (3) basic forms Bacteria, Fungi and Actinomycetes.

The result of soil microorganisms colony count (cfu^{-1}) based on growth performance in the study area is presented in Table 8. The results of the high growth performance site indicate that bacteria count ranged from 3.0×10^{-4} to 5.0×10^{-4} cfu/ml, fungi count ranged from 3.0×10^{-4} to 5.4×10^{-4} cfu/ml and actinomycetes count also ranged from 9.0×10^{-4} to 19.0×10^{-4} cfu/ml.

Results of the medium growth performance site indicate that Bacteria count ranged from 3.8×10^{-4} to 6.8×10^{-4} cfu/ml, fungi count ranged from 4.6×10^{-4} cfu/ml to 6.0×10^{-4} cfu/ml and actinomycetes count also ranged from 6.0×10^{-4} to 21.0×10^{-4} fu/ml.

From the low-performance site, results indicate that bacteria count ranged from 3.0×10^{-4} to 4.5×10^{-4} cfu/ml, fungi count ranged from 3.0×10^{-4} to 6.7×10^{-4} cfu/ml and actinomycetes count also ranged from 9.0×10^{-4} to 18.0×10^{-4} cfu/ml.

The result of high growth performance indicated the bacteria identified from the soil had five-gram reactions that were positive and one negative with four cocci clustered shapes, one bacillus and cocci in the chain.

The result of medium performing site indicates five positive gram reactions and one negative with one bacillus and five cocci clustered shape. The result of low low-performing site indicates four-gram reaction positive and two negatives with four cocci clustered, two bacilli and one coccus in chain shape (Table 9).

The result of the high-performing site indicates pigmentation with five cream colours and one cream *Pseudomonas* spp. The result of the medium-performing site indicates cream yellow in pigmentation while the result of the low-performing site indicates the same pigmentation as that of the medium-performing site (Table 10).

The result from the high-performing site indicates the presence of fungus in the soil and was dominated by *A. nigera*, followed by *A. fumigutum*, *A flavows*, penicilline, microspoerum spp, and panacea. The result from the medium-performing site indicates the presence of *A. nigera*, *A. fumigutum*, *A. flavows*, and penicilline. The

Table 8. Soil Micro - organisms (cfu^{-1}) based on growth performance in the study area.

Growth site	Location	Bacteria (cfu^{-1})	Fungi (cfu^{-1})	Actinomycetes (cfu^{-1})
High	P1	5.5 ×10^{-4} cfu/ml	80.0 × 10^{-4} cfu/ml	24.0 × 10^{-4} cfu/ml
	P2	6.7 ×10^{-4} cfu/ml	78.0 × 10^{-4} cfu/ml	22.7 × 10^{-4} cfu/ml
	P3	6.0 ×10^{-4} cfu/ml	83.5× 10^{-4} cfu/ml	24.5 × 10^{-4} cfu/ml
	P4	5.1 ×10^{-4} cfu/ml.	91.0 × 10^{-4} cfu/ml	23.0 × 10^{-4} cfu/ml
	P5	5.0 ×10^{-4} cfu/ml	75.0 × 10^{-4} cfu/ml	21.0 × 10^{-4} cfu/ml
	P6	6.8 ×10^{-4} cfu/ml	90.0 × 10^{-4} cfu/ml	20.0 × 10^{-4} cfu/ml
Medium	P1	4.9 ×10^{-4} cfu/ml	50.0× 10^{-4} cfu/ml	18.0× 10^{-4} cfu/ml
	P2	4.7 ×10^{-4} cfu/ml	35.0× 10^{-4} cfu/ml	20.0×10^{-4} cfu/ml
	P3	4.6 ×10^{-4} cfu/ml	61.0× 10^{-4} cfu/ml	16.7 × 10^{-4} cfu/ml
	P4	4.5 ×10^{-4} cfu/ml	50.0× 10^{-4} cfu/ml.	15.0× 10^{-4} cfu/ml
	P5	4.0×10^{-4} cfu/ml	35.0× 10^{-4} cfu/ml.	21.0 ×10^{-4}cfu/ml
	P6	4.5 ×10^{-4} cfu/ml	55.0× 10^{-4} cfu/ml	17.2× 10^{-4} cfu/ml
Low	P1	3.7 ×10^{-4}cfu/ml	13.10× 10^{-4} cfu/ml	7.0× 10^{-4} cfu/ml
	P2	3.8 ×10^{-4} cfu/ml	7.80× 10^{-4} cfu/ml	1.9× 10^{-4} cfu/ml
	P3	3.5 ×10^{-4} cfu/ml	7.60× 10^{-4} cfu/ml	6.0× 10^{-4} cfu/ml
	P4	3.0 ×10^{-4} cfu/ml	6.7 ×10^{-4}cfu/ml	1.8× 10^{-4} cfu/ml
	P5	3.5 ×10^{-4} cfu/ml	10.10 × 10^{-4} cfu/ml	9.0 ×10^{-4}cfu/ml
	P6	3.0 ×10^{-4} cfu/ml	12.80 × 10^{-4} cfu/ml	11.0× 10^{-4} cfu/ml

Key: Cfu = microorganisms per colony forming units (**Source:** Field Experiment, 2024).

Table 9. identified of gram-stained bacteria from soils of date plantation.

Growth site	S/no	Location	Gram reaction	Shape
High	1	P 1	+VE	Cocci clustered
	2	P 2	+VE	Cocci clustered
	3	P 3	+VE	Cocci clustered
	4	P 4	-VE	Bacilli
	5	P 5	+VE	Cocci clustered
	6	P 6	+VE	Cocci in chain
Medium	1	P 1	-VE	Bacilli
	2	P 2	+VE	Cocci clustered
	3	P 3	+VE	Cocci clustered
	4	P 4	+VE	Cocci clustered
	5	P 5	+VE	Cocci clustered
	6	P 6	+VE	Cocci clustered
Low	1	P 1	+VE	Cocci clustered
	2	P 2	-VE	Bacilli
	3	P 3	+VE	Cocci clustered
	4	P 4	+VE	Cocci clustered
	5	P 5	+VE	Cocci in chain
	6	P 6	-VE	Bacilli

Source: Field Experiment, 2024).

result of the low-performing indicates the presence of fungus in the soil and dominated by *A. nigera* and followed by *A. fumigutum*, *A flavows*, penicilline and strestomycete respectively (Table 11).

Table 10. Identification of actinomycetes from soils of date plantation.

Growth site	S/No	Location	Pigmentation
High	1	P1	Cream colour
	2	P2	Cream colour
	3	P3	Cream colour
	4	P4	Cream colour
	5	P5	Cream pseudomonas spp
	6	P6	Cream pseudomonas spp
Medium	1	P1	Cream yellow
	2	P2	Cream yellow
	3	P3	Cream yellow
	4	P4	Cream yellow
	5	P5	Cream yellow
	6	P6	Cream yellow
Low	1	P1	Cream yellow
	2	P2	Cream yellow
	3	P3	Cream yellow
	4	P4	Cream yellow
	5	P5	Cream yellow
	6	P6	Cream yellow

Source: Field Experiment, 2024.

Table 11. Identified of fungal from soils of date plantation.

Parameters	S/No	Location	Pigmentation
High	1	P1	*A. nigera*, *A. flavons*, *A. fumigatous*
	2	P2	*A. flavows*, *Parasiticum*
	3	P3	*Microsporum spp*, *A. nigera*, candid, panacea.
	4	P4	*A. fumigatus*, *A. niger*, *A. flavows*
	5	P5	*A. flavows*, penicillin, *A. niger*
	6	P6	*A. fumigatum*, *Penicillin*, *A. niger*
Medium	1	P1	*Penicilline, A. fumigatus, A. niger*
	2	P2	*A. flavows, Penicilline, A. niger*
	3	P3	*A. flavows, A. niger, Penicillin*
	4	P4	*A. flavows, A. niger, A. fumigatus*
	5	P5	*A. flavows, A. niger*
	6	P6	*A. flavows, A. niger, A. fumigatus*
Low	1	P1	*A. niger, A. flavows*
	2	P2	*Penicillin, A. flavows*
	3	P3	*A. niger, A. flavows, A. fumigatum*
	4	P4	*A. niger, A. fumigatum*
	5	P5	*A. fumigatum, A. niger*
	6	P6	*A. flavows, A. niger, strestomycete*

Source: Field Survey, 2024.

DISCUSSION

Soil physicochemical properties in the study sites

Soil physical properties of the study sites

The findings of this study show similarity in soil textural classes of sandy clay loam, sandy loam and loamy sand amongst the different sites evaluated based on growth performance and is in conformity to that reported by Gujja *et al*. (2022)and Jimoh *et al*. (2019) in their study of assessment of nutrient status in date palm plantation soils of Modibbo Adama University, Yola Adamawa State and evaluation of soil quality under date palm plantation for

climate change and food security in Gombe State University, Gombe Nigeria where they obtained sandy loam and loamy sand in the two studies.

The findings of this study show that sand dominates the soil fractions with a range value of between 72.4 and 80.4% across the different growth performance sites. The high content of sand in the study site could be partly due to pedogenic processes involving sorting soil materials by biological activities, clay migration through eluviation and illuviation, or surface erosion by runoff or their combinations. These findings are similar to those reported by Gujja *et al.* (2022) and Jimoh *et al*. (2019) in their study of date palm plantation soils where they obtained a mean value of sand 75% for high performing site, while the middle slope mean value was 80 gkg^{-1}. The similarity in high sand fraction could be partly attributed to parent material of the same ecological zone.

The findings of this study show bulk and particle densities amongst the three different sites based on growth performance to range from 1.43 to 1.64g/cm^3 and 2.54 to 2.73g/cm^3 and were also not significantly different areas of the sites. The range values of bulk density obtained from this study in all the sites are higher than those reported by Jimoh *et al*. (2019) in their studies, they obtained a mean value of 1.34 g/cm^{-3} for upper and middle slopes and Gujja *et al.* (2022) similarly reported a mean value of 1.49 to 1.53 g/cm^{-3} and 2.60 g/cm^{-3} to 2.61 g/cm^{-3} for upper and middle slopes, respectively. The bulk density range values obtained from this study might possibly have an adverse effect on the performance of the plant as reported by Arifin *et al*. (2012) in their study of selected soil properties for Tropical Soil Quality Index (TSQI) where values of bulk density ≥ 1.5 is said to likely affect the plant.

Soil chemical properties of the sites

The pH is recognized as a principal variable in influencing virtually every process in the soil system. The health of crops and other soil life, the availability of nutrients, and the activity of pesticides are all affected by pH (Omar, 2012). From this study, the pH range of soil samples was between 6.16 and 6.25 amongst the three different sites and based on growth performances. The soils are thus slightly acidic to near neutral at all sites. These findings conform with those reported by Jimoh *et al*. (2019) and Gujja *et al.* (2022) in their study of date palm plantations where the mean pH of soil stood at 6.33 at the upper slope and 6.34 at the middle slope and mean value of low 6.25, medium 6.19 and 6.16. Arifin *et al*. (2012) in their study of selected soil properties for Tropical Soil Quality Index (TSQI) where values of soil acidity ranged from 5.51 to 7.2 is said to be slightly acid to near neutral and optimum for many plant species growths.

The concentration of organic carbon in the sites evaluated based on growth performances revealed that it was significantly different (p≥0.05) amongst the performance sites and the values ranged from 0.811 to 1.011%, 0.692 to 0.718% and 10.732 to 0.810% at the high, medium and low-performance sites. The result of a low level of organic C might possibly be due to a high proportion of sand particles which might result in low aggregation, low water retention and poor physical stability of the soil. The level of organic C in this study is lower than that reported by Jimoh *et al*. (2019) where the mean values for organic carbon were higher at the upper slope (5.6 $g{\cdot}kg^{-1}$) than at the middle slope (5.0 $g{\cdot}kg^{-1}$). The variation can be attributed to disturbance regimes, soil layers, locations due to climatic, edaphic, biological, land management practices and vegetation.

Total nitrogen of the sites evaluated based on growth performances revealed significant differences (p≥0.05) amongst the performance sites and the values ranged from 0.140 to 0.174%, 0.119 to 0.124% and 0.126 to 0.140% at the high, medium and low-performance sites respectively. The sites showed moderate total nitrogen availability and were within the adequate levels of 0.1 to 0.5 % as rated by Arifin *et al*. (2012) in their study of selected soil properties for the Tropical Soil Quality Index (TSQI). The values obtained in this study are low when compared to that reported by Jimoh *et al*. (2019) in their study of date palm plantations where the mean values of total nitrogen concentration in the upper slope have a mean value of 1.4 $g{\cdot}kg^{-1}$ and middle slope mean value of 1.31 $g{\cdot}kg^{-1}$. The variation can be attributed to the rate of mineralization of organic carbon in the sites and also being a very mobile element, it is prone to loss easily through leaching and percolation under flooded situations.

The Av-p at the high, medium and low-performance sites were not significantly different (p≥0.05). The Av-p in this study which ranged from 7.475 to 12.637 mg/kg, 9.626 to 12.207 mg/kg and 9.195 to 11.777 mg/kg were low. Av-p low contents in soils could be related to the intensity of soil weathering or soil disturbance under the land use type. The values of these studies are low when compared to those reported by Jimoh *et al*. (2019) where the available phosphorus of upper and middle slope mean values were 22.06 and 25.0 $mg{\cdot}kg^{-1}$, respectively. The variation can be attributed to likely deficiencies of phosphorus in the soil which is in conformity with the rating by Arifin *et al*. (2012) where they rated < 15 as likely deficiencies of phosphorus in the soil.

The ECEC among the sites evaluated based on growth performances were without significant differences (p ≤ 0.05). The value ranges were from 9.606 to 11.688 cmol/Kg, 8.939 to 10.475 cmol/Kg and 9.495 to 11.164 cmol/Kg. The values obtained in this study are high when compared to those reported by Jimoh *et al*. (2019) where ECEC mean values of 4.64 and 4.44 cmol (+) kg^{-1} were reported for the upper and middle slopes, respectively. The findings may be attributed to low ECEC, an indication that the soils at their natural pH levels, remain low in CEC and therefore have a low capacity to retain nutrients.

The processes that affect the extent of basic cations also

affect the per cent base saturation of soils. PBS values were not significantly different (p≥0.05). The high, medium and low-performance sites had 70.853 to 82.121%, 70.405 to 79.864% and 64.748 to 75.418%, respectively. The values obtained in this study are low when compared to those reported by Jimoh *et al*. (2019) where Base Saturation (BS) mean values range from 94 to 93% for upper and middle slopes respectively. This can be attributed to high corresponding ECEC values in the various sites.

Diversity of macroinvertebrate species in the study sites

Findings of the soil macro-invertebrates showed that there was a total of 365, 139 and 153 individual species belonging to 11, 9 and 7 Taxa respectively, from the studied sites. This result is similar to the findings of Kabir (2020) but at variance with the report of FAO (2012), which observed that lands that are subjected to the application of chemicals decimate soil organisms. Although the Shannon wiener Diversity Indices of the study areas were within the same range, the species lists indicated a higher number of soil macro-invertebrates 'species in the higher growth performance site than the other two sites. These macro faunas are important components of forest soil biodiversity and are essential to the ecosystem function and play a vital role in decomposition, carbon and nutrient cycles, soil structure and water movement in soil (Gujja *et al*., 2023, Dominati *et al.,* 2010; Gholami *et al.,* 2017). Some factors are believed to be responsible for these organisms' distribution, abundance, diversity and richness in forest soils. These factors are; soil physico-chemical properties (Fonge *et al.,* 2013), topographic attributes (Coblentz and Riitters, 2004) and tree diversity (Korboulewsky *et al.,* 2016; Schelfhout *et al.,* 2017).

Soil microorganisms (cfu^{-1}) in the study areas

Findings of the soil microorganisms showed a wide diversity in the date palm plantation which were categorized based on high, medium and low performance sites. These microorganisms (bacteria, fungi and actinomycetes) influence plant diversity and productivity (van der Heijden *et al*., 2008; Gujja *et al.* 2023). This is because they play important roles in the nutrient cycles and energy flows, providing essential services to the forest ecosystem. Soil fungi, for example, have the function of catalyzing the turnover of complex organic resources, which can drive the degradation of organic matter. Bacteria generally utilize the easily available substrates decomposed by fungi. Conversely, they are affected by the plant communities as they depend on the products of plant photosynthesis: litter and rhizo-deposits (Wardle, 2006; Qiao *et al*., 2014; Prescott and Grayston, 2013). The microorganisms 'influence on plant diversity and productivity agrees with the findings of Lladó *et al.* (2017) who stated that bacteria commonly harbour genes encoding plant cell wall-degrading enzymes and contribute significantly to the decomposition of organic matter. In addition, bacteria are the major natural agents responsible for N fixation in forest ecosystems and for other ecosystem processes, such as mineral weathering leading to the release of inorganic nutrients. The roles of bacteria and fungi, however, should not be viewed as separate. The high abundance of fungal biomass in forest soils has multiple consequences for bacteria, including the creation of specific niches in the soil patches colonized by mycorrhizal fungi (i.e., the mycorrhizosphere) and soil mycelial mats, provision of nutrients via organic matter decomposition, and an increase in soil connectivity by fungal mycelia that allow certain bacteria to move across the environment.

Conclusion

The finding of this study revealed that there was no significant difference among the physical properties across the study site leading to the conclusion that soil physical properties may not have been responsible for the observed differences in the growth of the Date Palm plants- the plantation. A different pattern was however observed in the values of the chemical properties of the plantation where significant differences exist in organic carbon, organic matter and total nitrogen across this site. It can thus be concluded that the observed differences in the performance of the trees in the three sites may be a result of the difference in their levels of organic carbon, organic matter and total nitrogen among other factors.

Recommendation

Based on the findings of the study, the following recommendations were made:

1. The performance of the date palm in the plantation may not be limited to the parameters studied. The Agri silvicultural practice within the plantation may have played a greater role and the use of agrochemicals may have affected the growth of the plants.
2. Further studies to evaluate the effect of the chemicals on the growth performance of date palms is therefore recommended.

CONFLICT OF INTEREST

The authors declared that no competing interest exists.

REFERENCE

Adriano, S, Alba, N. M., & Patrizia, R. (2020) Soil macrofauna: A

key factor for increasing soil fertility and promoting sustainable soil use in fruit orchard agrosystems. *Agronomy*, *10*(4), 456.
Agbenin, J. O., & Tiessen, H. (1995). Phosphorus sorption at field capacity and soil ionic strength: kinetics and transformation. *Soil Science Society of America Journal*, *59*(4), 998-1005.
Aislabie, J., Deslippe, J. R., & Dymond, J. (2013). Soil microbes and their contribution to soil services. Ecosystem services in New Zealand–conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand. Pp. 143-161.
Arifin, A., Karam, D. S., Shamshuddin, J., Majid, N. M., Radziah, O., Hazandy, A. H., & Zahari, I. (2012). Proposing a suitable soil quality index for natural, secondary and rehabilitated tropical forests in Malaysia. *African Journal of Biotechnology*, *11*(14), 3297-3309.
Arifin, H. H. M., Abdu, A., Othman, R., Jusop, S., &. Karam, D. S. (2014). Impact of enrichment planting activity on soil physico-chemical properties of degraded forestland. *International Journal of Environmental Sciences*, *5*(2), 407-422.
Bhattarai, B., Beilin, R., & Ford, R. (2015). Gender, agro biodiversity, and climate change: A study of adaptation practices in the Nepal Himalayas. *World Development*, *70*, 122-132.
Black, C. A. (1965). Method of soil analysis part 11. Society of American Agronomy Incorporation Madison. WISCONSIN. USA.
Blake, G. R, and Hartz, K.H. (1986). Bulk density. In: Black, C. A (ed). *Methods of soil analysis part 11* (pp. 891-901). American society of agronomy incorporation. WISCONSIN, USA.
Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil science*, *59*, 39-46.
Bukar, S. M., & Abba, H. M. (2022). Vegetation Structure and Diversity in Northern Yobe, Nigeria. *Asian Journal of Plant Biology*, *4*(1), 36-42.
Coblentz, D. D., & Riitters, K. H. (2004). Topographic controls on the regional-scale biodiversity of the south-western USA. *Journal of Biogeography*, *31*(7), 1125-1138.
Dishan, E. E., Tella I. O., & Adaeze, J. E. (2018). Macro fauna species diversity and distribution under the influence of siltation and solid waste effluents along River Benue Bank, Adamawa State, Nigeria. *Journal of Forestry, Environment and Sustainable Development*, *4*(1), 1-10.
Dominati, E., Patterson, M., & Mackay, A. (2010). Response to Robinson and Lebron—Learning from complementary approaches to soil natural capital and ecosystem services. *Ecological Economics*, *70*(2), 139-140.
Durán, P., Barra, P. J., Jorquera, M. A., Viscardi, S., Fernandez, C., Paz, C., Mora, M. D. L. L., & Bol, R. (2019). Occurrence of soil fungi in Antarctic pristine environments. *Frontiers in Bioengineering and Biotechnology*, *7*, 28.
FAO (2012). Performance of the FAO Aqua Crop model for wheat grain yield and soil moisture simulation in Western Canada. *Agricultural Water Management*, *110*, 16-24.
Fonge, B. A., Tchetcha, D. J., & Nkembi, L. (2013). Diversity, distribution, and abundance of plants in Lewoh-Lebang in the Lebialem highlands of Southwestern Cameroon. *International Journal of Biodiversity*, Volume 2013, Article ID 642579, 13 pages.
Geographic Information System (2024). GIS Laboratory, Geography Department, Yobe State University, Damaturu Nigeria.
Getachew, B., Weldesemayat, G., Zenebe, G., Fantaw, Y., & Getachew, D. (2018). Soil macrofaunal diversity and biomass across different land use systems in Wondo Genet, Ethiopia. *Advances in Life Science and Technology*, *67, 17-23*.
Gholami, S., Sheikhmohamadi, B., & Sayad, E. (2017). Spatial relationship between soil macrofauna biodiversity and trees in Zagros forests, Iran. *CATENA*, *159*, 1-8.
Gujja, A. A., Dishan, E. E., & Nasiru, Y. (2022). Assessment of nutrient status in date palm plantation soils of Modibbo Adama University, Yola Adamawa state, Nigeria. *Asian Journal of Plant and Soil Sciences, 7*(1), 73-83.
Gujja, A. A., Mu'azu, A. A, Babagana, U & Tarimbuka L.Y (2023). Assessment of microbial isolates date palm plantation soils of Modibbo Adama University, Yola Adamawa State, Nigeria. *Journal of Agriculture and Forestry Research, 2*(2), 1-54.
Harold, V., Robert, S., Joseph, A., & Kirsten, K. (2020). Soil and crop sciences section comprehensive assessment of soil health. Bulletin from Soil Science Society of America.
International Institute of Tropical Agriculture (IITA) (1979). *Selected method for soil and plant analysis*, Manual Series No. 1. IITA, Ibadan, Nigeria.
Jimoh, K. Ibrahim, J. A. Jusop, S., & Karam, D. S. (2019). Evaluation of soil quality under date palm plantation for climate change and food security in Gombe State University, Gombe Nigeria. *EQA-International Journal of Environmental Quality*, *35*, 51-64.
Kabir, M. A. (2020). Evaluation of biodiversity status and the supporting systems in relation to socio-economic characteristics in Lakeshore Communities of Kainji Lake National Park, Nigeria. An Unpublished Ph.D. Thesis, Submitted to the Department of Forestry and Wildlife Modibbo Adama University, Yola. (MAUTECH).
Kekane, S. S., Chavan, R. P., Shinde, D. N., Patil, C. L., & Sagar, S. S. (2015). A review on physico-chemical properties of soil. *International Journal of Chemical Studies*, *3*(4), 29-32.
Koralage, I. S. A. Weerasinghe, P., Silva, N. R. N., & de Silva, C. E. (2015). The determination of available phosphorus in soil: A quick and simple method *OUSL Journal, 8*, 1-17.
Korboulewsky, N., Perez, G., & Chauvat, M. (2016). How tree diversity affects soil fauna diversity: A review. Soil Biology and Biochemistry, *94*, 94-106.
Lladó, S., López-Mondéjar, R., & Baldrian, P. (2017). Forest soil bacteria: diversity, involvement in ecosystem processes, and response to global change. *Microbiology and Molecular Biology Reviews*, *81*(2), 81(2), e00063-16.
Lucas-Borja, M. E., De Santiago, J. H., Yang, Y., Shen, Y., & Candel-Pérez, D. (2019). Nutrient, metal contents and microbiological properties of litter and soil along a tree age gradient in Mediterranean forest ecosystems. *Science of the Total Environment*, *650*, 749-758.
Masomeh, I., &, Hashem, H. (2016). Changes in diversity, biomass and abundance of soil macrofauna, *Parrotio-Carpinetum* forest at organic and semi-organic horizons, *Eurasian Journal of Soil Science, 5*(3), 166-171.
Moghimian, N., & Kooch, Y. (2013). The effect some of physiographic factors and soil physico-chemical features of hornbeam forest ecosystem on earthworms biomass. *Journal of wood and Forest Science and Technology*, *20*(2), 1-21.
Naher, A. U., Othman, R., & Panhwer, A. Q. (2013). Culturable total and beneficial microbial occurrences in long-term nutrient deficit wetland rice soil. *Australian Journal of Crop Science, 7*(12), 1848-1853.
Omar, U. Y. (2012). Effects of pesticides on soil enzymes: A review. *Environmental Chemistry Letters*, *12*(2), 257-273.
Osman, K. T. (2012). Plant nutrients and soil fertility management. In: *Soils: Principles, Properties and Management*. Springer Netherlands. Pp. 129-159.

Prescott, C. E., & Grayston, S. J. (2013). Tree species influence on microbial communities in litter and soil: current knowledge and research needs. *Forest Ecology and Management*, *309*, 19-27.

Qiao, J., Liu, Y., Hong, F., & Zhang, J. (2014). A review of catalysts for the electroreduction of carbon dioxide to produce low-carbon fuels. *Chemical Society Reviews*, *43*(2), 631-675.

Retallack, G. J. (2008a) Rock, views soil and plant at the template of ancient Greece Department of Geological Science, University of Oregon, Eugene Oregon 974034 – 1272 USA.

Retallack, G. J. (2008b). *Soils of the plant: An introduction to paleopedology* (2nd edition). John Wiley and Sons, UK. p. 207.

Schelfhout, S., Mertens, J., Verheyen, K., Vesterdal, L., Baeten, L., Muys, B., & De Schrijver, A. (2017). Tree species identity shapes earthworm communities. *Forests*, *8*(3), 85.

Scholten, T., Goebes, P., Kühn, P., Seitz, S., Assmann, T., Bauhus, J., Bruelheide, H., Buscot, F, Erfmeier, A, Fischer, M., Härdtle, W, He, J-S., Ma, K., Niklaus, P. A., Scherer-Lorenzen, M., Schmid, B, Shi X, Song, Z, von Oheimb, G., Wirth, C, Wubet, T., & Schmidt, K. (2017). On the combined effect of soil fertility and topography on tree growth in subtropical forest ecosystems—a study from SE China. *Journal of Plant Ecology*, *10*(1), 111-127.

Thomas, G. W. (1982) Exchangeable cations method of soil analysis part 2, chemical and microbiological properties second edition. Al page (editor) agronomy, No. 9 part 2 American society of agronomy, soil science of America Madison, wl: 159-165.

Tukur, R. (2013). *Access use and management of trees and shrubs in the savannah: an approach to environmental sustainability in northern Nigeria*. Lambert Academic Publishing. p. 97.

Umeri, C., Onyemekonwu, R. C., & Moseri, H. (2017a). Analysis of physical and chemical properties of some selected soils of rain forest zones of Delta State, Nigeria. *Agricultural Research and Technology Open Access Journal*, *5*(4), 555668.

Umeri, C., Onyemekonwu, R. C., & Moseri, H. (2017b). Evaluation of physical and chemical properties of some selected soils in Mangrove swamp zones of Delta State, *Nigeria. Archives of Agriculture and Environmental Science 2*(2), 92-97.

Unanaonwi, O. E. (2009). Acidity, Organic carbon and Nitrogen status of soils under *Acacia senegal* L. (Willd.) Plantation and Natural forest in Gummi forest reserve, Zamfara State, Nigeria. *Nigerian Journal of Forestry*, *38*(2), 91-99.

Unanaonwi, O. E. (2015). The role of trees in true development. *Journal of Agriculture and Ecology Research International*, *4*(2), 53-58.

Van Der Heijden, M. G., Bardgett, R. D., & Van Straalen, N. M. (2008). The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. *Ecology Letters*, *11*(3), 296-310.

Vieira, F. C. S., & Nahas, E. (2005). Comparison of microbial numbers in soils by using various culture media and temperatures. *Microbiological Research*, *160*(2), 197-202.

Wardle, D. A. (2006). The influence of biotic interactions on soil biodiversity. *Ecology Letters*, *9*(7), 870-886.

Yager, G. O., Agbidye, F.S., & Adma, E, S. (2017). Insect species diversity and abundance in and around the Federal University of Agriculture, Makudi Forestry Nursery. Benue state, Nigeria. *Asia Journal of Biology, 4*(4), 1-11.