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EKSU JOURNAL OF SCIENCE AND TECHNOLOGY

(EJST)

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CONTROL OF COWPEA BRUCHID (*Callosobruchus maculatus*) USING SELECTED CRUDE EXTRACTS OF G*arcinia kola*

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Abstract
The ravaging effects of cowpea bruchid (Callosobruchus maculatus) on the productivity and economic value of cowpea have become a major concern. The sustainable control of this pest have limited the frequent use of synthetic pesticides due to their toxicities. The comparative efficacy of the crude extracts of the leaf, seed, bark and fruit of Garcinia kola were assessed against C. maculatus. The bioassay was an in-situ 24-h static non-renewal test of the plant extracts against the bruchid. Results showed that all parts of the plant were active with varying degrees of mortalities. The seed extract appeared most potent with LC_{50} value of 8.49 g/ml, followed by the bark (10.77 g/ml), leaf (12.44 g/ml), and fruit (15.26 g/ml) respectively ($p<0.05$). These results confirmed the insecticidal activities of the crude extracts of the leaf, seed, bark, and fruit of this plant. It is therefore recommend that the crude extracts of G. kola will be useful for the formulation of pesticide used in the control of cowpea weevil known as C. maculatus.

Keywords: Cowpea, *Garcinia kola*, Crude extracts, *Callosobruchus maculatus*, Biopesticide

Introduction

Nigeria is a major producer of cowpea with over 2.5 million metric tons worth $633,956,000, followed by Niger and Mali. According to Yusuf *et al.*, (2011), it is the most important leguminous source of protein in the tropics and sub-tropical countries. Unfortunately, the overall productivity and marketability of cowpea have been threatened by bruchid postharvest pest called *Callosobruchus maculatus*.

Projections on plant-derived pharmaceuticals showed that over 70 of drugs are precursors of plants. For instance, *Artemisia annua*, is a plant that contain pharmaceutical agent called artemisinin which is used for the formulation of Artesunate (an anti-malaria drug) and other therapeutic efficacies (Brisibe, *et al.*, 2008). Maˇ nourová, *et al.* (2019) reported that African *Garcinia* species have been used in folkloric medicine for many centuries. In Nigeria, there is great medicinal importance of the nuts, bark and leaf of *Garcinia kola*.

Interestingly, reports had it that the plant parts showed very active pharmacological properties such as anti-bacteria (Ebana *et al.*, 1991), anti-oxidant (Tchghebe *et al.*, 2016), anti-viral (Iwu *et al.*, 1990), anti-fungal (Abah *et al.*, 2014), anti-malaria (Adaramoye *et al.*, 2014) and anti-inflammatory properties

(Olaleye, *et al.*, 2000). Due to the anti-oxidant and broadspectrum activities it has become necessary to investigate the insecticidal properties of *Garcinia kola* against *Callosobruchus maculatus*.

Materials and Methods

Collection and preparation of plant sample

The Leaves, seed, bark and fruit of *G. kola* was collected from vegetation of the forest ecosystem of Bayelsa State. The samples were transported to the Herbarium of the Department of Biological Sciences for identification.

Plant extraction procedures

Some 300 g of the pounded fresh leaf, seed, bark and fruit of *G. kola* were weighed distinctly with the aid of weighing balance (Satoric AG Gottingen Electronic). The weighed plant parts were specifically deliquesced in 500 ml hot water for 72 hours with prepared filter paper disc whose circumferences suit into the base of perforated Petri dishes. The decoctions were vaporized in a rotary evaporator at 60°C, allowing the residue to cool at room temperature and then preserved.

Bruchid culture/collection

The cowpea seed infested by *C. maculatus* (cowpea weevils) were kept in plastic container covered with fine mesh and transported to the laboratory. More cowpea seeds were added to increase feeding rate and reproduction. From the stock sample, mature cowpea weevils with infested cowpea seeds were separated and allowed to feed and mate for one week under laboratory conditions at temperature ranging from 25 – 28 °C, and relative humidity of 60% – 90%. After eggs were layed, the weevils were removed to allowing the larva reach maturity (Tiroesele *et al.*, 2018). After attaining maturity, the sex of the weevil were determined using elytral pattern examination. The females were maculated with four distinct elytral spots, as compared to males (Tiroesele *et al.*, 2018). This process was continued to generate more weevil for the bioassay.

Experimental setup

A minimum of 10 *C. maculatus* (cowpea weevil), were placed in a 500ml solution of the selected extracts at varying concentrations (5, 10, 15, 20, 25, and 30g/ml), in a 24-hour static non-renewal test. In accordance with World Health Organization guidelines (Agboola *et al.*, 2011), bioassay procedure was performed. Mortality rates (%), of beetles was recorded after 24 h exposure period. The experimental positive control was 1 ppm of Phosphine pesticide, while 500 ml of distilled H_2O was the negative control. The larvicidal screening protocols was 2-phase: rapid and final screening (Agboola *et al.*, 2011). Appropriate statistical analyses were carried out on the data for mortality rates.

Results and Discussion

Mortality rates for the final screening of all crude extracts of the leaf, seed, bark and fruit of *G. kola*, screened against the test organism (*C. maculatus*) is presented in Tables 1. Results of the crude leaf extract assayed against the pest, indicated that death/mortality rates ranged from 16.67 – 100.00%, while minimal and total mortality rates were recorded at 5 and 30 g/ml respectively (Table 1).

Table 1: Mortality rate for crude extracts of *G. kola*

Concentration (g/ml)	Mortality Rates (%)			
	Leaf	Seeds	Bark	Fruit
5	16.67±5.77a	33.33±5.77a	23.33±5.77a	6.67±5.77a
10	31.67±12.58b	51.67±7.63b	45.00±8.66b	18.33±2.88a
15	50.00±10.00c	66.66±5.77c	58.33±7.63c	36.67±5.77b
20	68.33±7.63d	85.00±8.66d	70.00±10.00c	53.33±5.77c
25	85.00±8.66e	100.00±0.00e	83.33±5.77d	78.33±12.58d
30	100.00±0.00f	100.00±0.00e	100.00±0.00e	100.00±0.00e

Data expressed as mean ± standard deviation, difference in alphabetical subscript along the column indicates level of significance

The insecticidal efficacy of the crude leaf extract was reported with an LC_{50} value of 12.44 g/ml (Figure 1). Crude seed extract of *G. kola* showed death/ mortality rates of between 33.33 – 100.00% (Table 1). While, the minimal mortality rate was recorded at concentration of 5 g/ml, the minimal total mortality was reported at concentration of 15 g/ml (Table 1). Seed extract of *G. kola* demonstrated an LC_{50} value of 1.38 g/ml (Figure 1).

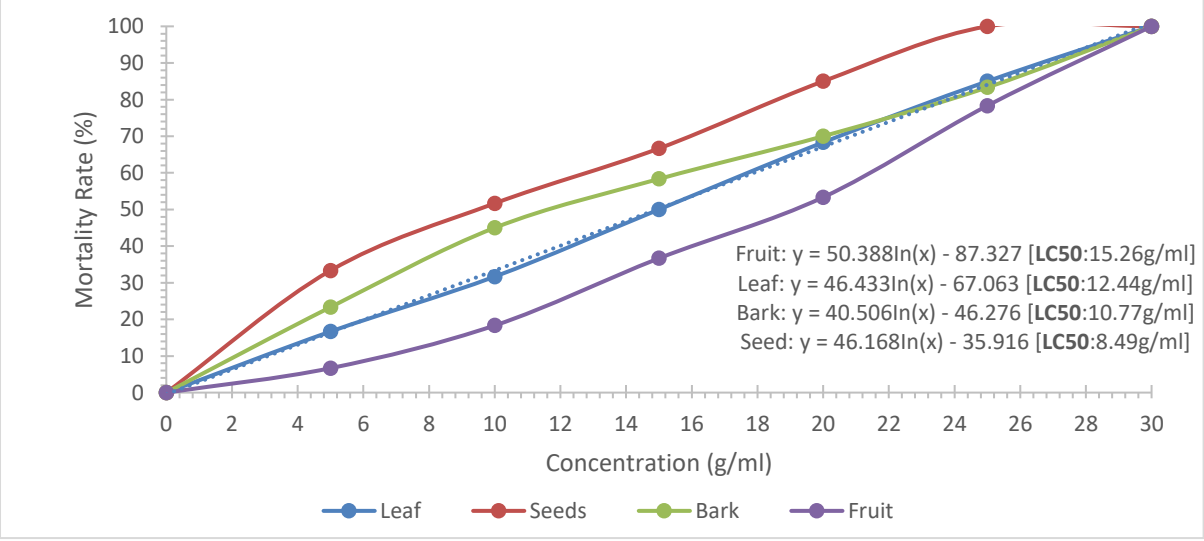

Figure 1: Dose-mortality curve for crude extracts of *G. kola*

Results of the bark extract tested against the weevil showed efficacy with mortality rates of 60.00 – 100.00% (Table 1). Comparatively, the least mortality rates of the bark and fruit extracts were similarly recorded at concentration of 5 g/ml, as well as 25 g/ml for the minimal total mortality (Table 1). Results of the insecticidal activity for the crude bark extract was demonstrated with LC_{50} value of 10.77 g/ml (Figure 1). The crude fruit extract of the plant was the least active inducing mortality with LC_{50} value of 15.26 g/ml (Figure 1).

In another study conducted by Radha and Susheela (2015), significant difference was observed in the eggs laying and F1 generation emergence of *C. maculatus in* cowpea seed treated with 0.5 and 1% for methanol, ethyl ether, and crude extracts of *Vitex negundo* and *Cassia fistula* leaves (Radha and Susheela, 2015). They also reported that, cowpea treated with methanol extract of *C. fistula* showed no significant difference between concentrations of 0.5 and 1%.

Azardirata indica have been reported as protectant against stored grains. According to Boeke *et al.* (2012), oils of *Cymbopogon nardus* and *C. schoenanthus* demonstrated ovicidal activities against eggs of *C. maculatus*. In addition, the authors also reported repellent effects for *Clausena anisata*, *C. citratus*, *C. nardus*, *C. flexuosus*, *Hyptis spicigera*, *Tagetes minuta* and *Ocimum basilicum.* The control of *C. Maculatus* was investigated with 50 grams of garlic, peppermint and chilies in 500 g of the cowpea seeds, while the Peppermint had significant fecundal suppression on cowpea weevils than garlic and chilies extracts (Bamphitlhi *et al.*, 2015).

The insecticidal and protectant activities of most plant-derived pesticides are not farfetched. The mechanism of action against most brichins and insects includes; disruption of eggs and larvae development, preventing pupation, molting, inhibiting fecundal and mating effort, repellence of oviposition, sterilizing adults, anti-federacy and digestive disrutption, prevention meta-morphosis, maturation, and inhibition of chitin formation which is essential for the insect exoskeleton development (Pandey and Singh, 2015). It is strongly believed that the phytochemicals which supported the antibacterial activities of *G. kola* must have been responsible for the mortalities of the *C. maculatus* that infested the cowpea.

Conclusion

This study investigated the insecticidal efficacies of the crude seed, bark, fruit and leaf extracts of *G. kola*. Fortunately, all crude extracts of the plant showed insecticidal potencies against the bruchid (*C. maculatus*). The order of activity was reported as Seed > Bark > Leaf > Fruit. Therefore extracts of *G. kola* has potential for *Callosobruchus maculatus* biopesticide production.

Declaration of Interest

The authors declared that there are no conflicts of interests.

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EFFECT OF *BUCCHOLZIA CORIACEA* ENGL. ETHANOLIC EXTRACT ON THE HAEMATOLOGICAL, SERUM BIOCHEMICAL PARAMETERS AND LIVER FUNCTION TEST OF MALE SPRAGUE – DAWLEY RATS

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Abstract

The high medicinal potential of Buccholzia coriacea Engl. has caused its high consumption which has necessitated the need to evaluate its impact on the haematology, serum biochemical parameter and liver function test of its consumer using an animal model (male Sprague dawley rat) in this study. Forty eight male rats weighting between 120 -150g were grouped into 4. All treatment groups were treated orally daily with B. coriacea seed ethanolic extract (BCSEE) at different dosage for 21 days. At the end of the experiment, the rats were anesthetized with ketamine/xylazine cocktail (0.1mL/20g), blood obtained via the aorta was analyzed for haematological, serum biochemical and liver function test parameters. There was a significant (P<0.05) different in the effect of BCSEE on haematology and serum biochemical parameter of the rats. The Packed cell volume (PCV), Red blood cells (RBC), haemoglobin and mean corpuscular haemoglobin concentration (MCHC) of the rats treated with B. coriacea was higher than what was obtained in the rats on the control treatment. The white blood cells (WBC), platelet (PLT), mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) was highest in low dosage of 100mg/kgbw BCSEE treatment, followed by the control, medium (200mg/kgbw BCSEE) and high (400mg/kgbw BCSEE) dosage which implies abnormalities which might be due to infection. The rats treated with BCSEE had significantly (P < 0.05) higher in the activities of Alanine aminotransferase (ALT) and Urea. It was observed that the BCSEE improved the status of the rat's haematology and serum biochemical parameters above the normal levels.

Keywords: *Buccholzia coriacea,* Haematological parameters, Serum biochemical parameters, Liver function parameter, Sprague – Dawley Rats

Introduction

The alarming rate of drug resistance is creating waves for the use of tradomecidine which makes the use of herbs an alternative to modern medicine. The challenge of drug resistance, emerging and re-emerging microbial infections is still persistence (Ezeigbo *et al.,* 2016; Izah *et al.,* 2018). Ejikeugwu *et al.,* (2014) postulated that drug resistant to different microbial strain is a major factor leading to the search of new antimicrobial agents. Some plants have proven to be a suitable alternative for the

synthetic and semi-synthetic based drug for the cure of several disease conditions (Izah *et al.,* 2018).

Buchhlozia coriacea is one of such plants as the leaves and seed have been reported to have anti-helminthic, anti-diabetic properties (Kameswararao *et al.,* 2003; Ezekiel and Onyeoziri, 2009) as well as antimicrobial properties (Nweze and Asuzu, 2006). *Buchhlozia coriacea is* popularly known as "Wonderful Kola" which was earned by the medicinal efficacy of the seed (Ezekiel and Onyeoziri, 2009; Mbata *et al.,* 2009; Ibrahim and Fagbohun, 2014; Nwachukwu *et al.,* 2014; Eze *et al.,* 2015; Ijarotimi *et al.,* 2015; Lapshak *et al.,* 2016; Umeokoli *et al.,* 2016).

Wonderful kola seed has been reported to contain essential amino acids, essential oil, fatty acids, minerals such as cations (calcium, magnesium, sodium and potassium), phosphorus, trace metals (copper, zinc, manganese, cobalt and nickel) and does not contain non-essential trace metals such as lead and chromium which is an indication that it could promote good health through diet (Ikpeazu *et al.,* 2017; Izah *et al., 2018*). The fermented, raw, and blanched seed of wonderful kola contain amino acids such as alanine, arginine, aspartic acid, cysteine, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, threonine, tryptophan, tyrosine, serine, valine with total amount of 68.96-73.31 mg/100 g and varying quantities of fatty acids including palmitic, palmitoleic, stearic, oleic, linoleic, linolenic, arachidic and behenic acid (Ijarotimi *et al.,* 2015).

Buccholzia coriacea has been reported by several authors to possess bioactive constituents which includes alkaloids, saponins, tannins, flavonoids, oxalates, phytates cardiac glycosides, steroids, resins, carbohydrate, anthraquinone, glycosides in seed of wonderful kola (Mbata *et al.,* 009; Ibrahim and Fagbohun, 2012; Nwachkwu *et al.,* 2014; Obiudu *et al.,* 2015; Okere and Ladeji, 2016; Umeokoli *et al.,* 2016). Wonderful kola possess essentials oil which contains both long chain saturated and unsaturated fatty acids, alcohols and their esters and high concentration of Estra-1, 3, 5 [10]-trien-17ß-ol according to Omorogie *et al.,* 2015; Umeokoli *et al.,* 2016; Ikpeazu *et al.,* 2017. It has also been confirmed to contain steroid and oleic acid, the steroid is the major constituent that is different from estradiol (a sex hormone), with the absence of an OH functional group at carbon atom number 3 and the oleic acid is unsaturated fatty acid which also considered as a healthy source of fat in human diets (Umeokoli *et al.,* 2016).
With all these amazing properties of the *Buccholzia coricea*, it's demand and consumption has increased tremendously. Hence, there is need to assess the effect of *Buccholzia coriacea* on the haematological and serum biochemistry parameter as well liver function test of Sprague – Dawley so as to assess *Buccholzia coriacea* effect on human health.

Materials and method

The research was conducted in the laboratory of the Department of Animal and Environmental Biology, Federal University Oye Ekiti, Ekiti State. The protocols used were approved by the

Institutional Animal Care and Usage Committee of Faculty of Science; Federal University Oye Ekiti, Ekiti State and ethical clearance obtain from Ekiti State University.

Preparation *B. coriacea* seed extract

Fresh seeds of *B. coriacea* were obtained from a market in Oye Ekiti, Nigeria. The seeds of *B. coriacea* were further identified and authenticated in the herbarium of Plant Science and Biotechnology Department of Federal University Oye Ekiti. The *B. coriacea* seeds were washed thoroughly to remove adhering particles. The *B. coriacea* seeds were sliced, shade-dried and pulverized. The powdered *B. coriacea* (2.5kg) were macerated in ethanol (80% v/v) for 24 hours. After that the extract was filtered through muslin cloth and plug of glass wool in a glass column. The filtrate was concentrated and evaporated to dryness using rotary evaporator at temperature of 40 ^{0}C, to avoid denaturation of active constituents. The extract was weighed and the percentage yield was calculated and recorded. The extract was stored in the refrigerator for further analysis. The dried down extract was reconstituted with distilled water for animal oral treatments.

Phytochemical analysis of ethanolic extract of *B. coriacea* seeds

The phytochemical composition of ethanolic extract of *B. coriacea* seeds was carried out using the methods described by Nwachukwu *et al.,* 2014.

Animals and treatment groups

Forty-eight male Sprague-Dawley rats weighing between the range of 120 - 150g were used for the study. The rats were acclimatized in plastic cages for two weeks at room temperature and given pelleted rat feed and fresh water *ad-libitum.* Ethical care and handling of experimental animals were observed at all times. The groups were: Control group receiving 2.5 ml of normal saline; Low dose group receiving 100 mg/kg body weight of *B. coriacea* seed extract; Medium dose group receiving 200 mg/kg body weight of *B. coriacea* seed extract; High dose group receiving 400 mg/kg body weight of *B. coriacea* seed extract. All *B. coriacea* groups were treated orally daily with *B. coriacea* for 21 days before termination of the experiment.

Blood sample collection

After completing the treatments, the rats were anesthetized with ketamine/ xylazine cocktail (0.1mL/20g) containing 87.5mg/kg ketamine and 12.5 mg/kg xylazine. The rats were then cut down on the abdominal skin to open up the thoracic artery. 3 - 4 ml of blood was collected directly from thoracic artery with heparinized syringe. The blood was analyzed for haematological parameters using the portable 5-part hematology analyzer (YSTE5000) and the serum biochemical parameters were analyzed using the portable semi-auto biochemical analyzer (YSTE-21). The liver function test parameters were later assessed. Serum biochemical parameters were determined using commercially available kits (BIOSINO Biotechnology and Science INC, China). Randox kits for AST, ALT and ALP were obtained from

Randox Laboratories Limited, United Kingdom and were assayed by the method described by Reitman and Frankel (1975). Determination of serum creatinine was carried out using Jaffe's method described by Bowers and Wong (1980). Urea was estimated using urease-Berthelot's method described by Cembrowski *et al.,* 1993. Serum sodium and potassium ions were measured by the method of AOAC (2019) and bicarbonate ion was determined using the titration method of Segal (1995).

Statistical analysis

Data were reported as means± SE. One-way and two-way analysis of variance (ANOVA) were used to analyze the data and the group means obtained after each treatment has been compared with control measurement were separated using Duncan multiple test range and $P < 0.05$ was considered as the level of significance.

Results

Percentage yield of extract

The percentage yield was calculated and recorded as:

$$\text{Percentage yield} = \frac{\text{weight (g) of the extract}}{\text{weight (g) of Pulverized seeds}} \times 100 = \frac{175.8\text{g}}{2000\text{g}} \times 100 = 10.27\%$$

Phytochemical screening

Phytochemical screening of the ethanolic extract of *B. coriacea* shows the presence of flavonoids (1750.52±28. 22mg/hg), tannins (26.16±7.00 mg/ hg), terpenoids (803.63 ± 3.12mg/hg), phenols (94.86 ± 3.43), alkaloids (50. 91±2.21mg/hg), glycosides (8.04± 0. 12mg/hg), steroids (0.33± 0.10mg/hg), saponins (0.30 ± 0.08mg/hg) and cyanides (0.16 ± 0.10mg/hg) as presented in Table 1.

Table 1: The phytochemical composition of ethanolic *B. coriacea* seed extract in mg/hg.

Phytochemical constituents	Concentration (mg/100 g)
Flavonoids	1750.52 ± 28.22
Tannins	26.16 ± 7.00
Terpenoids	803.63 ± 3.12
Phenols	94.86 ± 3.43
Alkaloids	50.91 ± 2.21
Glycoside	8.04 ± 0.12
Steroids	0.33 ± 0.10
Saponins	0.30 ± 0.08
Cyanide	0.16 ± 0.10

There was a significant increase in the body weight of the rats. Although there was a progressive decrease in weight gain of the rats with increase in the ethanolic extract of *B. coriacea* administered as shown in Table 2. There was a significant ($P<0.05$) different in the effect of *B. coriacea* seed ethanolic extract on studied haematological parametersof the rats. The PCV of the rats treated with 100mg/kgbw BCSEE (42.51 ± 8.32%) and 200mg/kgbw BCSEE dosage (41.04 ± 6.42%) of *B. coriacea* was higher than the PCV obtain in the rats on the control treatment (40.38 ± 6.02%), which indicate it boosted the PCV to a particular dosage as presented in Table 3. The number of RBC and Heamoglobin increased significantly in the treatment of 100mg/kgbw BCSEE and 200mg/kgbw BCSEE compared with the controls (Table 3). 400mg/kgbw BCSEE treatment decreased in RBC count compared the control.

Table 2: The effect of *B. coriacea* seed ethanolic extract on the weight gain of the male albino rats

Group	**Initial Body Weights (g)**	**Final Body Weights (g)**	***Body Weight Gain (g)***
Control (2.5 ml of normal saline)	133.12 ± 6.02	170.21 ± 8.32	37.09 ± 2.12[a]
Low Dose (100mg/kgbw BCSEE)	129.54 ± 3.56	139.38 ± 4.79	9.84±3.13[b]
Medium Dose (200mg/kgbw BCSEE)	131.76 ± 2.94	138.78±4.70	7.02±3.26[c]
High Dose (400mg/kgbw BCSEE)	137.31 ± 4.09	141.79 ± 5.76	4.48±1.41[d]

[abcd] *Means with different superscripts on the same column are significantly different (p<0.01).*

Table 3: The effect of *B. coriacea* seed ethanolicextract on the haematological parameters of the male albino rats

Parameters	CONTROL (2.5ml normal saline)	LOW DOSE (100mg/kgbw BCSEE)	MEDIUM DOSE (200mg/kgbw BCSEE)	HIGH DOSE (400mg/kgbw BCSEE)
PCV (%)	40.38 ± 6.02[c]	42.51 ± 8.32[a]	41.04 ± 6.42[b]	38.76±6.45[d]
WBC (mm^3)	9234.54 ± 276[b]	9982.38 ± 288[a]	8863.41±273[c]	7782.22±273[d]
RBC ($\times 10^6/\mu L$)	6.76 ± 2.94[c]	8.78±4.70[a]	7.65±3.26[b]	6.21±2.99[d]
Hb (g/dL)	14.31 ± 4.09[c]	15.79 ± 5.76[a]	14.42±3.13[b]	13.85±4.69[d]
PLT($x10^5$/ µL)	3.56±0.5[b]	3.71±0.9[a]	3.43±0.7[c]	3.28±1.0[d]
MCV(fL)	76.98±20.09[b]	77.74±20.28[a]	75.69±20.00[c]	73.47±21.70[d]
MCH(pg)	25.83±3.51[b]	26.96±4.80[a]	25.71±4.81[c]	24.67±3.21[d]
MCHC(g/ dL)	35.61±12.20[c]	37.54±12.70[a]	36.35±12.30[b]	35.14±12.01[d]

[abcd] *Means with different superscripts on the same column are significantly different (p<0.01).*

The WBC was highest in 100mg/kgbw BCSEE dosage treatment (9982.38 ± 288 mm^3) followed by the control (9234.54 ± 276 mm^3), 200mg/kgbw BCSEE treatment (8863.41±273 mm^3) and 400mg/kgbw BCSEE dosage (7782.22±273 mm^3), respectively. There was a significant increase MCV MCH, MCHC in 100mg/kgbw BCSEE dose treatment but decreased in 200mg/kgbw BCSEE and 400mg/kgbw BCSEE dose treatments compared to the control (Table 3). Platelets (PLT), increasing significantly in 100mg/kgbw BCSEE dosage treatment, whereas the other treatments differ significantly as compare with the control (Table 3). There was a significant ($P<0.05$) different in the effect of *B. coriacea* extract *on* serum biochemical parameters of the albino rats. It was observed that *B. coriacea* extract improved the status of the serum biochemical parameters above the normal levels.

Table 4: The effect of *B. coriacea* seed ethanolicextract on the Serum biochemical parameters of the male albino rats

Parameters	Control (2.5 ml of normal saline)	Low Dose (100mg/kgbw BCSEE)	Medium Dose (200mg/kgbw BCSEE)	High Dose (400mg/kgbw BCSEE)
Glucose (mmol/L)	5.72 ±0.23 [b]	5.98±0.20 [a]	6.04 ± 0.42[a]	6.76±0.45[c]
Protein (g/L)	68.96±1.43 [d]	72.34±2.42[c]	75.20±2.52[b]	77.47±2.71[a]
Albumin (g/L)	36.81±2.10[c]	36.98±2.57[b]	37.61±3.04[a]	36.21±2.99[d]
TG(mg/dL)	14.31 ± 4.09[b]	15.79 ± 5.76[a]	14.42±3.13[c]	13.85±4.69[d]
TC(mmol/L)	3.56±0.5[b]	3.71±0.9[a]	3.43±0.7[c]	3.28±1.0[d]
HDL(mg/dL)	76.98±20.09[b]	77.74±20.28[a]	75.69±20.00[c]	73.47±21.7[d]
LDL(mg/dL)	25.83±3.51[b]	26.96±4.80[a]	25.71±4.81[c]	24.67±3.21[d]

[abcd] *Means with different superscripts on the same row are significantly different (p<0.01).*

The rats treated with *B. coriacea* extract had significantly ($p < 0.05$) higher activities of Alanine aminotrans-ferase (ALT) and Urea in serum when compared to rats in the control group (Table 5). However, the effect of *B. coriacea* extract significantly ($p < 0.05$) lowered the activities of serum AST, ALP, creatinine, Sodium, Chloride and Potassium when compared with control rats.

Table 5: The effect of *B. coriacea* seed ethanolic extract on the liver and kidney function test parameters of the male albino rats

Parameters	Control (2.5ml normal saline)	Low Dose (100mg/kgbw BCSEE)	Medium Dose (200mg/kgbw BCSEE)	High Dose (400mg/kgbw BCSEE)
Alanine transaminase (U/ L)	75.61±12.20 [c]	77.54±12.70 [a]	76.35±12.30 [b]	75.14±12.01 [d]
Aspartate transaminase (U/L)	117.85±0.95 [a]	117.75±0.68 [b]	117.05±0.66 [c]	116.75±0.74 [d]
Alkaline phosphatase (U/L)	63.650±1.50 [a]	63.050±0.90 [b]	62.450±0.74[c]	62.150±0.50 [d]
Urea(mmol/L)	9.03±0.15[d]	9.58±0.06 [c]	9.72±0.08 [b]	10.05±0.36 [a]
Creatinine(mmol/L)	64.95±1.03 [a]	64.72±1.10 [b]	64.60±1.11 [c]	64.34±1.02 [d]
Sodium (mmol/L)	143.05±1.61[a]	142.55±1.16 [b]	141.75±1.32 [c]	140.04±1.02 [d]
Pottasium(mmol/L)	5.92±0.48 [a]	5.13±0.24 [b]	5.07±0.63 [c]	5.01±0.11 [d]
Chlorine(mmol/L)	105.65±0.04 [a]	105.65±0.04[a]	104.45±0.32 [b]	103.25±0.54 [d]
Bicarbonate (mmol/L)	26.02±0.10 [a]	24.45±3.11 [c]	24.05±2.324 [d]	24.75±2.41 [b]

[abcd] *Means with different superscripts on the same row are significantly different (p<0.01).*

Discussion

Phytochemical screening of the *B. coriacea* shows the presence alkaloids, flavonoids, tannins and saponins in different concentrations and known to exhibit different biochemical and pharmacological actions which ranges from cell toxicity to cell protective effects in different species of animals when ingested (Trease and Evans, 1996; Uboh *et al.,* 2010). The presence of flavonoids have been reported to have antioxidative

effects (Price *et al.,* 1987) while the presence of saponins in the extract are known to have hypocholesterolemic activities (Kregiel *et al.,* 2017), which could help in reducing the metabolic stress on the liver.

The reduction in weight gain in rats treated with *B. coriacea* seed extract was experience. The higher the dosage of *B. coriacea* seed extract administered the lower the weight gain disagrees with the results of Omayone, 2018 who reported increase in weight gain with increase in dosage of *B. coriacea* seed extract administered.

The high rating of the *B. coriacea* as a medicinal plant of diverse potential might be attributed to the presence of the bio-active compound such alkaloids, tannins, saponins, etc. in it. Alkaloids are heterocylic compounds with micro-biocidal properties (Chang *et al.,* 1977). It has been proven as a central nervous system stimulant, which is also been used as anaesthetic, analgesic, antibacterial, etc. (Trease & Evans, 1989; Agte *et al.,* 2000). The presence of the high tannin content might be partly responsible for the hot taste of *B. coriacea* seeds and this tannin is toxic to filamentous fungi, yeast and bacterial hence the implication of the antifungal and antibacterial property (Jones *et al.,* 1994). The presence of tannin in *B. coriacea* could also be responsible for its anti-diarrheic and anti heamorrhagic property (Asquithand, 1986). The *B. coriacea* extract posses a good amount of saponin content. Saponins impedes Na^+ efflux by the obstruction of the entry of the Na^+ out of the cell which leads to increase in Na^+ concentration in the cells, activating a Na^+/Ca^{2+} anti porter in cardiac muscle. The increase in Ca^{2+} influx through this anti porter braces the contraction of heart muscle (Heikens *et al.,* 1995). The saponins presence in *B. coriacea* might imply that it posses' anti hyper-cholesterol; hypotensive and cardiac depressant properties. It also posses good concentration of glycosides (2.16 and 2.46%) for ethanolic and methanolic extract respectively which have been used for more than two centuries as stimulants in treatment of cardiac failure and cardiac disease (Olayinka *et al.,* 1992) that justified the use of *B. coriacea* seeds for tradomedical treatment and management of hypertension. Flavonoids might aid in furnishing protection against diseases such as cancer, ageing, inflammation, atherosclerosis, ischemic injury, neurodegenerative diseases (Anderson, 2004) by supplying along with antioxidant vitamins and enzyme, to the total antioxidant defense system to the human body.

The PCV dropped with higher dosage of BCSEE although the PCV for all treatments were within the standard PCV range for male rats as reported by Sharp and La Regina (1998). WBC levels increased significantly at low dosage concentrations of *B. coriacea* extract shows that the extract posses some components that stimulated the production of these regulatory factors or increased the sensitivity of the committed stem cells (responsible for the production of white blood cells) as well as an immune boosting property similar to that reported for garlic (*Allum sativum*) by Iranloye (2002) and seed extract of *Citrus paradisi* Macfad (Adeneye, 2008). Platelet values obtained in this research

are in the normal range of 638 - 1177 (10^3 / mL) (Das and Murherje, 2003). MCHC, MCH and MCV relate to individual red blood cells while Hb, RBC and PCV portray the total population of red blood cells in the blood (Sarma, 1990; Adebayo *et al.*, 2005) though the *B. coriacea* extract may invigorate the production of red blood cells and haemoglobin which could imply that it acquires an inhibitory effect on haemoglobin incorporation into red blood cells and a consequent reduction in oxygen exchange. Normally MCHC in male rats was 35.1 g / dl (Das and Murherje, 2003) whereas in this study the levels of MCHC rats treated 100mg/kgbw BCSEE dose and 200mg/kgbw BCSEE dose are respectively 37.54 and 36.35 g / dl.

Glucose, TC, TG and LDL values obtained in this research are in the normal range of (62.4 -201.8 mg/dl; 11.4-81.7 mg/dl, 8.7 – 60.7 mg/dl and -20.66 – 49.82 mg/dl 11), respectively. HDL value obtained in this research is not in the normal range of 9.7 - 42.1mg/dl (Delwatta *et al.,* 2018). Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) obtained are in the normal range of (1-223.3 U/L and 0.2 – 838.3 U/L) while AP is not in the normal range of 160.8 - 838.3U/L (Delwatta *et al.,* 2018). Increased alanine aminotransferase (ALT) and a lower aspartate aminotransferase (AST) ratio (AST/ALT ratio) observed in 100mg/kgbw and 200mg/kgbw BCSEE dosage treatments may suggest non-alcoholic fatty liver disease and nonalcoholic steatohepatitis which might increase the risk of liver cirrhosis and hepatocellular carcinoma (Ozaki *et al.,* 2020). The increase in ALT was also observed by Fakoya (2017) which has been attributed to the damaged structural integrity of the liver, because these are normally located in the cytoplasm and are released into the circulation after cellular damage (Vermeulen, 1992). Lower sodium concentration in all treatment administered with BCSEE could be as a result of increase fluid loss from body due to diarrhea experience in the course of the experiment as reported by Al-Awquati, 2020. Lenka *et al.,* 2016 recorded no significant difference in the all electrolytes, urea, creatinine and serum levels of all liver marker enzymes assayed which disagrees with results obtained in this study.

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BIOACTIVITY OF *DIODIA SCANDENS* AND *PHYLLANTHUS AMARUS* COLUMN FRACTIONS ON METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* AND *PSEUDOMONAS AERUGINOSA*

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Abstract

Bioactive constituents of plants are secondary metabolites or phytochemicals with great therapeutic benefit, which are used in traditional medicine. The aim of this study was to determine the antibacterial potency of the bioactive fractions of Diodia scandens and Phyllanthus amarus on Methicillin Resistant Staphylococcus aureus and Pseudomonas aeruginosa. Soxhlet ethanol extraction was conducted on pulverized whole plants, column chromatography was employed to separate the fractions of the extract using different solvent system of n-hexane: ethyl acetate as the mobile phase. MRSA and P. aeruginosa were subjected to four concentrations (0.4mg/ml, 0.3mg/ml, 0.2mg/ml, and 0.1mg/ml) for the determination of minimum inhibitory concentrations (MIC). 174 eluted fractions were pooled into 18groups based on color similarities (DA-DI & PA-PI). The solvent system of 70:30 had the highest bioactive fractions with R_f values of 0.55, 0.67, 0.74, 0.84, 0.87, 0.91, 0.95 in D. scandens and 0.14, 0.68, 0.77, 0.80, 0.89, 0.91 in P. amarus. Most fractions of both plants exhibited moderate to significant antibacterial activity against the test organisms with the MIC values ranging between 0.1 - 0.4 mg/ml for MRSA and P. aeruginosa. The current data justify the traditional usage of D. scandens and P. amarus as antibacterial agents, which should be promoted.

Keywords: *Diodia scandens, Phyllanthus amarus,* MRSA, *Pseudomonas aeruginosa*, column fractions, Antibacterial

Introduction

The use of plant derived medicines for the treatment of diseases by man has been in practice for many decades. History has it that these plants naturally synthesize or contains some bioactive constituents known as secondary metabolites that made them of a great therapeutic benefit. These secondary metabolites may include; alkaloids, sterols, terpenes, flavonoids, saponins, glycosides, tannins, resins, quinines (Motaleb *et al.*, 2011).

Local medicine has been of great interest since there is an increase in the demand of natural drug products over orthodox medicine. This is as a result of consumers belief that plant derived medicines are safer with no side effects, cheaper and more dependable than orthodox drugs

which are costly and have adverse side effects (Okwulehie and Akanwa, 2013). This was corroborated by Adegoke *et al.* (2010) who noted that Ribavirin, an antiviral drug could cause anemia.

Some bacteria have since the advent of antibiotics developed resistance mechanism against antibiotics. The rate of infections by antibiotic resistant strains has been on the increase for few decades as a result of the indiscriminate use of antibiotics especially in the developing countries and the microbial characteristics for resistance (Ojo *et al.*, 2018). Most clinical isolates of *Staphylococcus aureus* and *Pseudomonas aeruginosa* are discovered to be multi-drug resistant, resistant to penicillin, erythromycin, clindamycin, ciprofloxacin, fluoroquinolones, streptomycin, gentamycin, ampicillin (Adegoke *et al.*, 2010).

Since the use of medicinal plants in the treatment of infections has been found effective, it is therefore extremely important to study a wide variety of the active components of the plants *Diodia scandens* and *Phyllanthus amarus* for the purpose of providing a natural, safer and affordable treatment against diseases especially by multi-drug resistance strains (Ojo *et al.*, 2018).

This present study however aims to determine the antibacterial potency of the column fractions of bioactive constituents of *D. scandens* and *P. amarus* on Methicillin Resistant *Staphylococcus aureus* (MRSA) and *Pseudomonas aeruginosa*.

Materials and Methods

ollection of Plant Material

Diodia scandens and *Phyllanthus amarus* whole plant were collected from different locations within Federal University Oye-Ekiti campus and its environs during the rainy season (May/June). The plants were identified by a Professor of Botany at the Department of Plant Science and Biotechnology, Federal University Oye-Ekiti, Ekiti State, Nigeria.

Sample Preparation

The leaves of *D. scandens* and *P. amarus* were washed in distilled water, and then air dried under shade at room temperature for two weeks. The dried plant was crushed into fine powder with the aid of an electric blender. The powder was then sieved to remove larger leaf particles, then re-blended and sieved again. It was then stored in an air-tight container till required for use.

The ethanolic extracts of the active ingredients of the plants were obtained using the method described by Etta *et al.* (2011). Pulverized plant of 120g was extracted with 1.2L absolute ethanol by soxhlet extraction for 5hours. The ethanolic extracts were then evaporated into molten form by rotary evaporation.

Separation of Fractions of the Extract using Column Chromatography

Column chromatography was employed in this study to analyze the compounds present in the crude plant extract of the solvents using ethyl acetate and n-hexane. The column was packed with silica gel slurry (25g) and the mobile phases (mixture of ethyl acetate and n-hexane at different ratios) were applied

at various spots on the column (Omodara *et al.*, 2013).

This was followed with the addition of n-hexane to the column so as to pack the silica gel and remove any air gap in the column. The addition of this solvent was continuous till it was seen coming out of the column into a test tube. 1.0g of the ethanol extract was thoroughly mixed with chloroform and placed on steam bath until the ethanol solvent remaining in the extract was totally removed which turned to powder form. Once the solvent level has drained to just above the silica, the column was loaded by adding the extract to the top of the column.

Fresh n-hexane was continually added with replacement to avoid drying out of the column until a yellow band was observed separating from the green extract to the bottom of the column. The yellow band was collected into another test tube. 100% n-hexane was first used to run the column, followed by n-hexane: ethyl acetate solvent ratios at different concentrations (70:30, 60:40, 50:50, 30:70, and 20:80 and 100% ethyl acetate). This was carried out in order to increase the separation of different component contained in the plant extract. This is to move the green band through the column. As the green band approaches the bottom of the column, it was collected into another test tube. TLC was carried out on the original ethanol extract, using capillary tubes for application on a TLC plate about 1.5cm from the edge (spotting line) using capillary tubes. The R_f (Retention factor) was reference and the various bands or spots were noted.

Isolation and Identification of Test Organisms

Methicillin Resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa* were obtained from the Drug Discovery and Development Research (DDDR) unit of the Department of Microbiology, Federal University Oye-Ekiti and plated on freshly prepared nutrient agar and incubated at 37˚C for 24hours and stored on nutrient agar slant for subsequent use.

Antibiotics Susceptibility Testing of Test organisms

Antimicrobial screening was carried out by disc diffusion method on the test organisms. The inocula were prepared by diluting 24hours old culture into 5ml of Mueller Hinton broth (MHB) and incubated for 6hours. The culture was diluted in sterile normal saline (0.9v/v) suspension and then matched with the 0.5 McFarland standards (Ojo *et al.*, 2013). Mueller Hinton agar was seeded with standardized inocula before placing the commercially available antibiotic discs on the lawn of culture and incubated overnight at 35°C as positive control.

Determination of Minimum Inhibitory Concentration

A stock solution with a concentration of 100mg/ml was prepared by weighing 10mg of fractions of extract and dissolved in 100µl of 5% DMSO (Dimethyl sulfoxide). Working solutions of four fractions (0.1mg/ml, 0.2mg/ml, 0.3mg/ml, and 0.4mg/ml) were prepared from the stock solution. The various concentrations were prepared as follows:4µl of fraction of stock solution + 6µl of 5% DMSO = 0.4mg/ml; 3µl of

fraction of stock solution + 7µl of 5% DMSO = 0.3mg/ml; 3µl of fraction of stock solution + 8µl of 5% DMSO = 0.2mg/ml; 3µl of fraction of stock solution + 9µl of 5% DMSO = 0.1mg/ml.

Overnight Mueller Hinton broth cultures (50µl) of MRSA and *P. aeruginosa* were introduced into microtitre plate containing 50µlMueller Hinton broth with 2µl of the working fractions. The procedure was repeated for all the fractions (0.4mg/ml, 0.3mg/ml, 0.2mg/ml, and 0.1mg/ml) against test organisms separately. The microtitre plates were incubated at 35-37°C for18-24hours and were examined for any turbidity.

Results

The column fractions obtained using n-Hexane: ethyl acetate solvent systems of the ethanol crude extract of *D. scandens* was 88 and *P. amarus* was 86, which were pooled together based on similar colour of fractions to yield 9 groups each (DA –DI for *D. scandens* and PA – PI for *P. amarus*) (Table 1). The 80:20 solvent system fractions produced more of yellow-coloured pooled fractions while 70:30 solvent systems produced yellow and green-coloured pooled fractions for *D. scandens* and *P. amarus* respectively.

Table 1: Column chromatographic separation of *P. amarus* and *D. scandens* crude extract with different solvent system

	P. amarus				***D. scandens***			
S/N	ID No	Weight (g)	Solvent system	Colour of fraction	ID No.	Weight (g)	Solvent system	Colour of fraction
1	PA	0.22	100% n-H	Yellow	DA	0.4	100% n-H	Yellow
2	PB	0.6	80:20 n-H:Et	Yellow	DB	1.4	80:20 n-H:Et	Yellow
3	PC	0.6	70:30 n-H:Et	Green	DC	0.8	70:30 n-H:Et	Yellow
4	PD	0.17	60:40 n-H:Et	Light Green	DD	0.42	60:40 n-H:Et	Light Green
5	PE	0.42	40:60 n-H:Et	Light Green	DE	0.17	40:60 n-H:Et	Light Green
6	PF	0.82	50:50 n-H:Et	Light Green	DF	0.80	50:50 n-H:Et	Light Green
7	PG	0.3	30:70 n-H:Et	Colourless	DG	2.0	30:70 n-H:Et	Colourless
8	PH	0.24	20:80 n-H:Et	Light Yellow	DH	0.20	20:80 n-H:Et	Light Yellow
9	PI	0.2	90:10 n-H:Et	Colourless	DI	0.1	90:10 n-H:Et	Colourless

Key: PA- *P. amarus* pooled fractions A; DA- *D. scandens* pooled fractions A; n-H- n-Hexane; Et- Ethyl acetate

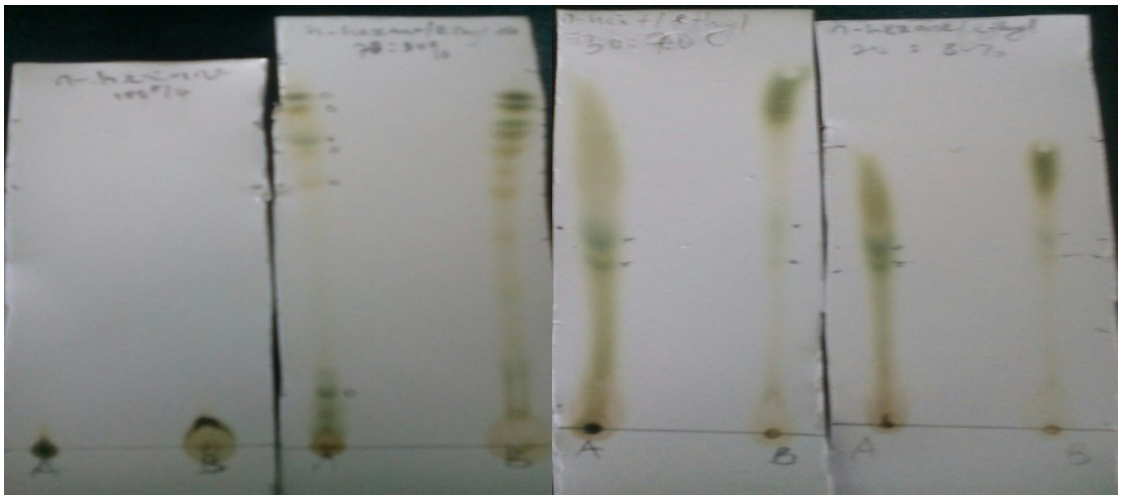
The TLC mobile phase yielded between 2 and 4 fractions at the 20:80, 30:70, 40:60, 50:50, and 60:40 n-hexane/ethyl acetate solvent system for both *D. scandens* and *P. amarus* while the 100% n-hexane yielded 1 fraction each for *D. scandens* and *P. amarus*. We observed that the retention factors (R_f) of the plant crude extracts at the 70:30 solvent systems were at0.55, 0.67, 0.74, 0.84, 0.87, 0.91, 0.95 for *D. scandens* and 0.14, 0.68, 0.77, 0.80, 0.89, 0.91 for *P. amarus*. Conversely, in the 30:70 solvent systems only 2 fractions were obtained for *P. amarus* and *D. scandens* with R_f values at 0.49, 0.56 and 0.48, 0.59 respectively. In the 80:20 solvent systems,4 fractions were obtained from *P. amarus* (with R_f values at0.14, 0.46, 0.58, and 0.91) and 7 fractions from *D. scandens* (with R_f

values at 0.44, 0.52, 0.60, 0.66, 0.74, 0.87, 0.90) crude extracts; while only 2 fractions were obtained in the 20:80 solvent systems with R_f values of 0.58, 0.64 and 0.61, 0.69 for *P. amarus* and *D. scandens* respectively (Table 2 and Figure 1).

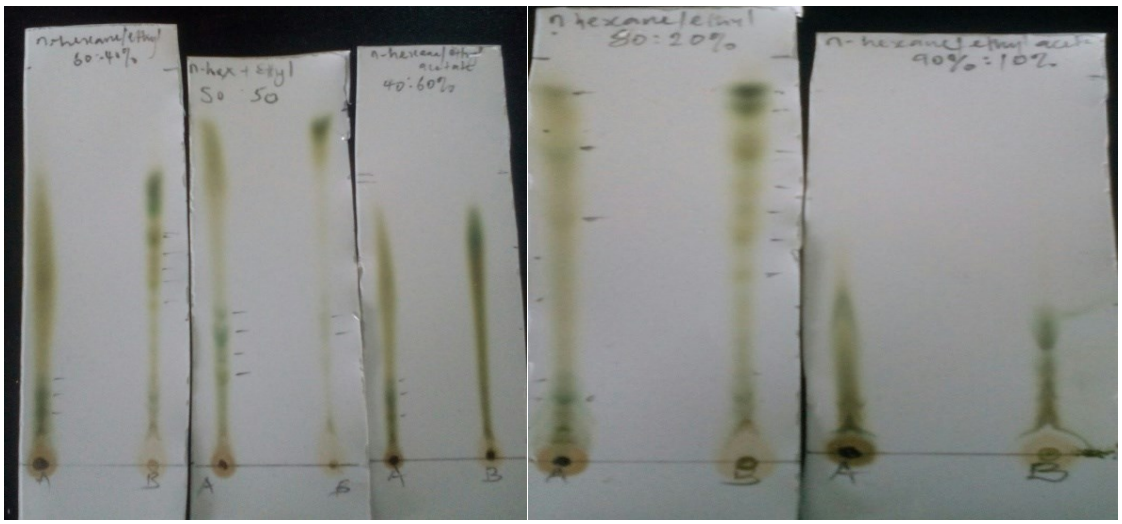
Table 2: R_f-values of bioactive fractions of *P. amarus* and *D. scandens* eluted by n-Hexane (100%) and n-Hexane: ethyl acetate solvent system

Solvent system	***Phyllanthus amarus***		***Diodia scandens***	
	No. of fractions	R_f values	No. of Fractions	R_f values
100% n-H	1	0.76	1	0.79
80:20 n-H:Et	4	0.14, 0.46, 0.58, 0.91	7	0.44, 0.52, 0.60, 0.66, 0.74, 0.87, 0.90
70:30 n-H:Et	6	0.14, 0.68, 0.77, 0.80, 0.89, 0.91	6	0.55, 0.67, 0.74, 0.84, 0.87, 0.91, 0.95
60:40 n-H:Et	3	0.17, 0.23, 0.31	4	0.56, 0.63, 0.72, 0.80
50:50 n-H:Et	4	0.24, 0.28, 0.35, 0.41	4	0.10, 0.29, 0.37, 0.43
40:60 n-H:Et	3	0.14, 0.23, 0.27	2	0.11, 0.86
30:70 n-H:Et	2	0.49, 0.56	2	0.48, 0.59
20:80 n-H:Et	2	0.58, 0.64	2	0.61, 0.69
90:10n-H:Et	1	0	1	0

Key: n-H:Et – n-Hexane:ethyl acetate; R_f – Retention factor



I **II** **III** **IV**



V **VI** **VII** **VIII** **IX**

Figure1: (**I**) TLC plate showing fractions eluted from *P. amarus* and *D. scandens* extract

Key: A- *Phyllanthus amarus* extract; B- *Diodia scandens* extract (I-100% n-hexane; **II**- 70:30% of n-hexane: ethyl acetate; **III**- 30:70% of n-hexane: ethyl acetate; **IV**- 20:80% of n-hexane: ethyl acetate; **V**- 60:40% of n-hexane: ethyl acetate; **VI**- 50:50% of n-hexane: ethyl acetate; **VII**- 40:60% of n-hexane: ethyl acetate; **VIII**- 80:20% of n-hexane: ethyl acetate; **IX**- 90:10% of n-hexane: ethyl acetate)

The results of the Minimum Inhibitory Concentration (MIC) of *P. amarus* and *D. scandens* fractions against MRSA and *P. aeruginosa* are shown in Table 3. The tested fractions of *P. amarus* and *D. scandens* against MRSA were observed to exhibit MIC value of 0.3mg/ml for fraction PA & DA; 0.2mg/ml for fraction PB & DB; 0.3mg/ml for fraction PE & DE; 0.4mg/ml for fraction PF & DF; 0.1mg/ml for fraction PG & DG, and 0.2mg/ml for fraction PH & DH, while there was no inhibition for fractions PC & DC and PD & DD.

Table 3: Minimum Inhibitory Concentration of *P. amarus* and *D. scandens* fractions against MRSA and *P. aeruginosa*

Strain		***Phyllanthus amarus*** Fractions										***Diodia scandens*** Fractions									
	Concentration (mg/ml)	PA	PB	PC	PD	PE	PF	PG	PH	PI	CT-P	DA	DB	DC	DD	DE	DF	DG	DH	DI	CT-D
MRSA	**0.4**	NT	NT	T	T	NT	NT	NT	NT	ND	NT	NT	NT	T	T	NT	NT	NT	NT	ND	NT
	0.3	NT	NT	T	T	NT	T	NT	NT	ND	NT	NT	NT	T	T	NT	T	NT	NT	ND	NT
	0.2	T	NT	T	T	T	T	NT	NT	ND	NT	T	NT	T	T	T	T	NT	NT	ND	NT
	0.1	T	T	T	T	T	T	NT	T	ND	NT	T	T	T	T	T	T	NT	T	ND	NT
Pseudomonas aeruginosa	**0.4**	NT	NT	T	T	ND	ND	ND	ND	ND	NT	NT	NT	T	T	ND	ND	ND	ND	ND	NT
	0.3	T	T	T	T	ND	ND	ND	ND	ND	NT	T	T	T	T	ND	ND	ND	ND	ND	NT
	0.2	T	T	T	T	ND	ND	ND	ND	ND	NT	T	T	T	T	ND	ND	ND	ND	ND	NT
	0.1	T	T	T	T	ND	ND	ND	ND	ND	NT	T	T	T	T	ND	ND	ND	ND	ND	NT

Key: T-Turbid; NT- Not Turbid; ND- Not Determined; PA-I: *P. amarus*fractions; DA-I: *D. scandens* fractions; CT- Negative control (0.4mg/ml fraction+Mueller Hinton Broth)

Moreover, among the tested fractions of *P. amarus* and *D. scandens* against *P. aeruginosa*, only fractions PA & DA and PB & DB exhibited an MIC value of 0.4mg/ml respectively. The results also showed that the fractions of *P. amarus* and *D. scandens* at lower concentrations had an antibacterial effect against MRSA while higher concentrations would be needed against *P. aeruginosa* (Table 3).

The antibiotic susceptibility pattern, which is the positive control, revealed that MRSA and *Pseudomonas aeruginosa* were resistant to most of the Gram positive and Gram-negative antibiotics respectively with few variations in susceptibility (Table 4).

Table 4: Antibiotics susceptibility pattern of MRSA and *P. aeruginosa*

Antibiotics	**Zones of inhibitions (mm)**		**Antibiotics**	**Zones of inhibitions (mm)**	
Gram positive	**MRSA**	***Pseudomonas aeruginosa***	**Gram negative**	**MRSA**	***Pseudomonas aeruginosa***
Pefloxacin	19.7±0.6 (S)	22.9±0.2 (S)	Septrin	16.7±1.5 (*S*)	10±0 (*R*)
Gentamycin	19.4±0.6(*S*)	10±0 (*R*)	Chloramphenicol	16.5±1.5(*R*)	11±0(*R*)
Ampiclox	19.3±0.7(*R*)	13±0(*R*)	Sparfloxacin	16.5±1.5(*R*)	24.8±0.2(*S*)
Zinnacef	19.3±0.5(*S*)	15.8±0.2(*R*)	Ciprofloxacin	16.5±1.6(*R*)	25.8±0.2(*S*)
Amoxicillin	11±0(*R*)	11±0(*R*)	Amoxicillin	12±0(R)	11±0(*R*)
Rocephin	19.3±0.6(R)	11±0(R)	Augmentin	11±0(R)	11±0(*R*)
Ciprofloxacin	19.3±0.6(*R*)	24.8±0.2(*S*)	Gentamycin	16.7±0.6(S)	11±0(*R*)
Streptomycin	19.4±0.5(*S*)	15.8±0.2(*R*)	Pefloxacin	16.7±0.6(R)	24.9±0.1(*S*)
Septrin	19.5±0.8(*S*)	12±0(*R*)	Tarivid	16.3±1.3(R)	18.9±0.5(S)
Erythromycin	19.3±0.7(*R*)	16.8±0.3(*R*)	Streptomycin	16.6±1.5(R)	23.8±0.2(S)

Key: R= Resistant, S= susceptible

MRSA exhibited resistance against ampiclox (19.3±0.7mm), chloramphenicol (16.5±0.7 mm), erythromycin (19.3±0.7mm), ciprofloxacin (19.3±0.6mm) while the findings also revealed that *P. aeruginosa* showed resistance against gentamicin (11±0mm), erythromycin (16.8±0.3mm), chloramphenicol (11±0mm) (Table 4). However, MRSA was sensitive to pefloxacin (19.7±0.6mm), gentamicin (19.4±0.6mm) while *P. aeruginosa* was sensitive to streptomycin (23.8±0.2mm), sparfloxacin (24.8±0.2mm) and ciprofloxacin (25.8±0.2mm).

Discussion

The upsurge in the resistance rate of clinical isolates to existing antibiotics in the last few decades has fueled inefficacy of many antimicrobial agents, leading to limited or even unavailable therapeutic options for the treatment of infectious diseases (Desalegn and Andualem, 2004; Pitout and Laupland, 2004), and hence justifies the high antibiotic resistance rate reported in the present study. Nevertheless, medicinal plants could be exploited as an alternative as their pharmacological properties coupled with antimicrobial activity are well known (Frankam *et al.*, 2017). In this regard, the present study is sought to unravel the bioactivity of *D. scandens* and *P. amarus* column fractions on MRSA and *P. aeruginosa* to further justify the previously reported antibacterial efficacy of the crude extracts of both plants (Sule and Agbabiaka, 2008; Ojo *et al.*, 2010; Akinjogunla *et al.*, 2012) coupled with their potential usage in traditional medicine for treating microbial infections.

Exploration into the fractionation of the crude extracts of *D. scandens* and *P. amarus* using different solvent systems of n-hexane: ethyl acetate revealed varying elution capacities as evident by the total number of fractions eluted by each solvent system. The TLC profiling of the crude extracts of both plants yielded an impressive result by unveiling the number of fractions or phytochemicals present in

each crude extract. This was further affirmed by the varying R_f values exhibited by the fractions in the present study. In this regard, it is important to emphasize that phytochemicals exhibiting high R_f value in less polar solvent system have low polarity while those with less R_f value have high polarity (Udoidong *et al.*, 2014). Hence, the observed disparities in R_f values in the present study may be attributed to the polarity of phytochemicals (Udoidong *et al.*, 2014), thus aiding the selection of appropriate solvent system for separation of pure compounds by column chromatography.

On this note, the mixture of n-hexane/ethyl acetate in ratio 70:30 was observed to be the most suitable mobile phase solvent in the present study based on the separation and numbers of fraction eluted from both plants. This observation is comparable to that of Irawan *et al.* (2017) who observed that the elution efficiency of a mixture of n-hexane/ethyl acetate was at maximum when the concentration of n-hexane surpasses that of ethyl acetate. In the same vein, the elution efficiency of a mixture of hexane and ethyl acetate was also appraised by Espinoza *et al.* (2008) while working on *Idriella* spp. extract. The observed differences in the elution capacities of the solvent systems employed in the present study agrees with the claim of Vivian (2003) who stated that the elution of compound(s) is dependent on the polarity of the solvent(s), that is, when the ratio of solvent is polar, the more polar compounds will be eluted while the less polar ones will be eluted if the ratio is less polar.

Eloff (2004) and Kuete (2010) documented that plant extracts exhibiting MIC value of 0.1 mg/ml or lower have a significant antimicrobial activity. Nevertheless, the antimicrobial activity is considered moderate if the plant extracts exhibit $0.1<MIC\leq0.625$ mg/ml and weak if MIC>0.625mg/ml. On this basis, all the tested fractions of *D. scandens* and *P. amarus* except for group C, D and I in the present study had moderate to significant antibacterial activities against MRSA with MIC values ranging from 0.1mg/ml to 0.4 mg/ml while only fractions A and B among other tested fractions against *P. aeruginosa* exhibited moderate antimicrobial activity with MIC value of 0.4 mg/ml. This data therefore suggest that these fractions could be helpful in combating bacterial infections, especially in traditional medicine. Moreover, fraction G from both plants gave the highest antibacterial activity against the test organisms, with *P. aeruginosa* requiring more concentration of the fractions of both plants than MRSA.

The findings of the antibacterial efficacy of the fractions from *D. scandens* and *P. amarus* crude extracts in the present study justify the previously reported remarkable bioactivity of the crude extract of both plants against clinical isolates (Sule and Agbabiaka, 2008; Ojo *et al.*, 2010; Akinjogunla *et al.,* 2012; Etta *et al.*, 2011). However, the earlier reported MIC values of the crude extracts of *D. scandens* {50mg/ml by Ojo *et al.* (2010)} and *P. amarus* {80 mg/ml by Akinjogunla *et al.* (2012); 50 mg/ml by Sule and Agbabiaka (2008); 50mg/ml to 200mg/ml by Ojo *et al.* (2010)} are considerably higher than what we

reported for the tested fractions in the present study. These variations may be attributed to the fact that fractionation of crude extracts yields more active samples.

This observation corroborates with that of Mambe *et al.* (2019) who also recorded maximum antibacterial potency from fractions of *Acacia polyacantha* crude extracts. Moreover, the observed lower concentrations exhibited by the fractions of *D. scandens* and *P. amarus* in the present study aligns with the claim of Etame *et al.* (2018) who stated that fractionation plays an important role in the search for antimicrobial from plants. Generally, the present data strongly imply that some fractions of *D. scandens* and *P. amarus* have excellent antibacterial activity that may even have good or higher activity than commercially used antimicrobials in the field or clinical trials (Eloff *et al.*, 2007; Eloff *et al.*, 2010).

Conclusion

The current data strongly justify the antibacterial promising features of *Diodia scandens* and *Phyllanthus amarus* in phytomedicine as majority of the fractions of the two plants exhibited remarkable antibacterial activities, and hence their traditional usage for combating bacterial infections should be promoted.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding this study.

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TECHNICAL EFFICIENCY OF VEGETABLE PRODUCTION VIS-À-VIS THE LOCKDOWN IN SOUTHWEST, NIGERIA

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Abstract

The study examined the technical efficiency of vegetable farming during and after the Covid-19 lockdown in Southwest Nigeria. It specifically addressed the socioeconomic characteristics of the farmers, the estimated cost, and the returns of vegetable production both during and after the COVID-19 lockdown. A Multistage random sampling was employed in the study. The first stage was a random selection of three (3) States from the six (6) States in South West, Nigeria. Three (3) Local Government Areas were randomly chosen from each selected State. Two (2) communities were sampled randomly from each of the Local Government Areas selected and random sampling of fifteen (15) farmers from each community, giving a total of 270 respondents. Descriptive statistics, Budgetary analysis, Technical efficiency using VRS and CRS criteria and Ordinary least squares (OLS) Regression Analysis were applied to data collected. The result showed that majority (41.9%) of respondents were in the active age with the mean age of 42 years. Majority (67%) of the respondents were male with household size ranging between 4 and 6 persons. About (64.1%) were married with an average year of farming experience of 31 years. The profitability analysis revealed the net farm income realized during and after COVID-19 was N124,393.9 and N258,587.3 per hectare, respectively. According to the calculation of the gross margin, the value per hectare during and after COVID-19 was N146,219.8 and N270,374.4, respectively. During and after COVID-19, the Benefit Cost Ratio was 2.85 and 4.6 which indicate that for every one naira spent, ₦2.85 and ₦4.6 will be realized as revenue respectively, implying that vegetable production is profitable in the study area. Results of the regression (OLS) analysis showed the basic variables that significantly influenced profit generation during COVID-19 scenario are quantity of vegetable output, gender of the farmer, farmers year experience and cost of labour while variables that influenced profitability after COVID-19 are quantity of vegetable output, gender of the farmer, marital status, household size and access to credit. The results also revealed a considerable inefficiency during-COVID period and this suggests that some of the vegetable farmers were not operating at an efficient scale and improvement in the overall efficiencies could be attained if the vegetable farmers modified their scale of operations. The study found that as the age of vegetable farmers increase, their profit decrease across all production scenarios, a policy that focuses on ways to attract and encourage young people who are agile and strong to start growing vegetables will help to boost technical efficiency and their income. Education should also be encouraged among vegetable farmers in the study area since the study revealed that education will enable them to adopt new technologies that will make them to have more profit from their production.

Keywords: Technical, Efficiency, Lockdown, Vegetables, Vis-à-vis, South-west, Nigeria.

Introduction

A virus called Coronavirus Disease (COVID-19) first surfaced in the Chinese city of Wuhan in December 2019. Dr. Li was the first to identify the virus, and the disease soon spread to a worldwide scale, prompting the World Health Organization (WHO) to declare the illness a pandemic on March 11, 2020. (WHO, 2020). The disease's rapid expansion has drew the attention of medical professionals, academics, and other researchers all over the world, who are trying to figure out the cause, how it spreads, and what can be done to stop it. COVID - 19 is active and stable at temperatures below 6 degrees Celsius, but loses potency as the temperature rises, according to Madhukalya and Kapoor (2020). Warmer weather, according to Russman et.al (2020), may impede the spread of this virus however, not everywhere in the globe. The COVID-19 epidemic was caused by the SARS-CoV-2 virus (formerly known as Corona virus). Since World War II and the founding of the United Nations, the COVID-19 pandemic has presented the world with its biggest challenge. (UN, 2020). It is believed to have started in Wuhan, Hubei Province, China, in December 2019. COVID-19 is still spreading over the world. China initially served as the outbreak's focal point, with cases being reported there or among Chinese tourists. On February 27, 2020, the first verified case of the 2019 coronavirus pandemic in Nigeria was disclosed, when an Italian citizen in Lagos tested positive for the virus (NCDC, 2020). Clearly, the emergency is medical or epidemiological in origin. This outbreak is assumed to have direct and indirect effects on household food security, livelihoods, and economic activity in Nigeria and the rest of the countries. The effect of the Corona virus outbreak on food security is projected to grow in scope, scale, and severity as the pandemic continues. Furthermore, the pandemic is occurring in areas where food insecurity is already a major issue.

The government imposed urgent adaptation of standard physical distancing and lockdown strategies, especially in urban centers, rural settlements, and places affected by active pandemics, to avoid adding a food crisis to the existing health crisis, which would otherwise 2 exacerbate the pandemic's negative effects. Due to the COVID-19 pandemic's transportation restrictions and lockdown, there was a labor shortage that reduced agricultural output (Ayetoro, 2020).

The impact of the COVID-19 pandemic on agriculture has grown in importance with the pandemic's worldwide spread in the context of contemporary agricultural development. Numerous angles have been used to study how the pandemic has affected agribusiness (Henry 2020; Morton, 2020). Small holders farmers in Nigeria were taken aback when the government imposed a lockdown at the end of March. Security personnel-imposed mobility restrictions indiscriminately over the country, many farmers could not access their fields. Farmers' access to markets was severely hampered as well. Because most small-scale farmers lack storage facilities, they were forced to either let their vegetables rot or sell them for a low price to unscrupulous intermediaries

Vegetables are essential for human nutrition because they provide essential vitamins, minerals, and fibre. They are essential anti-oxidant foods that are also extremely beneficial for improving fitness and preventing sickness. They include cherished food components that may be used to successfully accumulate and rejuvenate the body. Vegetables are important for maintaining the body's alkaline reserve. Their high vitamin and mineral content is the key reason for their popularity. Vegetables come in a variety of shapes and sizes. Edible roots, stems, leaves, fruits, and seeds are all possibilities. Each group makes a unique contribution to the diet. Fleshy roots have high energy content and are high in vitamin B. Carbohydrates and proteins are abundant in seeds. Minerals, vitamins, and water are abundant in leaves, steam, and fruits. Vegetable consumption in Nigeria is increasing year after year, owing to a growing appreciation of their nutritional value (Osalusi, 2019). Exotic vegetables are a distinct category of vegetables in Nigeria. They're well-known for their distinct flavor, nutritional content, and health advantages. They aid in maintaining the body's fluid equilibrium. Vegetable production as a small-scale enterprise can financially empower the underprivileged, particularly women with little capital, access to land, and labor constraints (Lewis, 1997). They are well-known for their distinct flavor, nutritional content, and health advantages. They contribute greatly to home food security and enable women achieve some degree of financial freedom within the family budget with the money they offer.

Problem statement

COVID-19 and the associated economic issues, according to many studies, will lead to a global food catastrophe, mainly in Africa, if the food system is unable to adapt (Blanke, 2020). According to previous studies, half of Africans are already food insecure, with half of them being seriously food insecure, and the number of hungry people is expected to treble by 2020. According to several research, the African continent is already facing food security issues (Blanke, 2020). African farmland is already being impacted by locust swarms in the Horn of Africa, local conflict, insecurity, and drought brought on by climate change. These catastrophes cause the loss of crops and incomes for millions of smallholder farmers in Africa (Brookings, 2020). Aside from that, the COVID-19 pandemic's arrival has weakened and exacerbated current output and distribution. capacity, particularly in SSA (Blanke, 2020).

The difficulties facing Africa during and post COVID-19 pandemic are grave, necessitating major actions focused on critical sectors in order to speed the reform of the food system and reduce rising food insecurity and poverty. According to the 2019 Global Food Report, world hunger is on the rise (WFP, 2019). Poverty and hunger are increasing in practically all African sub-regions, making Africa the region with the highest prevalence of hunger, with an increasing proportion of farming households experiencing food insecurity (GODAN, 2020). The 2019 edition demonstrates that considerable obstacles remain in the fight against food insecurity and poverty in all forms.

The arrival of COVID-19 has exacerbated the country's food crises and severe poverty levels. This consequence is quite concerning, as it jeopardizes the livelihoods of the world's poorest people, the majority of whom rely on agriculture (GODAN, 2020). The COVID-19 has already increased the likelihood of acute food insecurity for most farming households (GODAN, 2020). During times of crisis, the world's poorest people are more likely to run out of food, resulting in hunger and, in extreme cases, going days without eating, putting their health and wellness at risk (FAO, 2019). The COVID-19 epidemic has had a major effect on the production and supply chain of vegetables. Let's take the delivery of vegetables as an example. In Nigeria, the delivery of vegetables from the fields to the consumer includes a number of stages, including production, transportation, wholesale, and retail.

Vegetable output has decreased as a consequence of the pandemic's impact on production and the supply chain, which has also caused problems. Furthermore, vegetable production is unappealing due to the time-consuming processes involved, and high production costs are relatively high due to the relative high cost of labor, input costs, and supply chain complications caused by the impact of covid-19, affecting farmers' income and standard of living. As a result, this study investigates the impact of COVID-19 lockdown on vegetable farmers and their income generation in Southwest, Nigeria. Consequently, this study seeks and hopes to provide answers to the following pertinent research questions such as:

i. what are the socio-economic characteristics of the vegetable farmers in the study area?
ii. what are the costs and returns of vegetable production during and after the lockdown?
iii. what are the factors influencing the profitability of vegetable in the study area?
iv. what are the technical efficiencies of vegetable farmers in the study area?
v. What are the factors determining the technical efficiency of vegetable farmers

Objectives of the Study

The general objective of the study is to investigate the effect of COVID-19 lockdown on vegetable production and farm-income generation in Southwest, Nigeria. Specifically, the research objectives are to;

i. describe the socio-economic characteristics of the vegetable farmers in the study area;
ii. estimate the cost and return of vegetable farmers during and after the COVID-19 lockdown;
iii. determine the factors influencing the profitability of vegetable in the study area.
iv. examine the technical efficiency of vegetable production in the study area;
v. determine the factors influencing the technical efficiency of vegetable farmers in the study area.

Justification

The coronavirus (COVID-19) outbreak has significantly impacted Nigeria's economy, particularly the agricultural

industry and farm households. Due to the lockdown, mobility restrictions, reduced availability of labor and other inputs, and reductions in output prices resulting from drops in demand for commodities in specific market segments, farm enterprises have encountered production problems. Farm households may also be harmed by the loss of salaries and benefits from off-farm labor, which they rely on to fund farm production demands, household living expenses, investments, and debt payments. While various studies have looked at how the pandemic might affect global and national economic indicators like global poverty, government spending, GDP growth, budget deficits, and employment (ILO 2020a; ILO 2020b; Nicola et al. 2020; Sumner *et al.* 2020; UN-Habitat and WFP 2020; World Bank 2020).

There is a scarcity of data on how the epidemic and attendant lockdown restrictions impacted individuals in farm households. As a result, it's difficult to comprehend the repercussions and support mechanisms at the farm household level that can be used to assure income smoothing. Furthermore, given the high degree of unpredictability in the spread of the COVID-19 infection and the severity of the effects at the international level, a comprehensive analysis of the pandemic's impact on socioeconomic characteristics, agriculture, dietary intake, and food security is not yet available as far as we know, owing to the fact that the pandemic is still ongoing globally. As a result, it is critical to comprehend COVID-19's immediate socioeconomic ramifications, as well as how COVID-19 will affect the earnings and standard of living of vegetable farmers.

This study, which will contribute to the growing body of literature on the COVID-19 pandemic, looked at the financial effects of the COVID-19 outbreak and the induced lockdown restrictions in South-West Nigeria, as well as the implications on vegetable farmers and their income with their standard of living. Based on the effect of the lockdown on their quality of life, the results will aid researchers in better understanding the urgent needs of farm families in rural areas as well as the variables that affect their ability to generate income. The results will also be used as a supplement to existing knowledge to inform policy talks about farmers' livelihood coping mechanisms during the COVID-19 pandemic and to support decision-making on how to protect the livelihoods of vegetable growers who are the most vulnerable to the pandemic. This study will also act as a roadmap for other academics who want to do more research in this area. As a result, the purpose of this research is to look at the economic losses caused by the COVID-19 pandemic in terms of agricultural labor loss, income generation, and other accounting expenses like labor cost, as well as to offer potential solutions for addressing the COVID-19 pandemic's effects on farmers in Southwest Nigeria who produce vegetables.

Materials and Methods

The Study Area

The research was done in Southwest, Nigeria using a representative selection of 3 states. The zone is made up of six

States which are; Ekiti, Ondo, Osun, Ogun, Oyo and Lagos (Fig. 1), while the representative states are Lagos, Osun and Ekiti. The area lies between longitude 30°and 7°E and latitude 4°and 9°N with a total land area of 77,818 km2. National Population Commission, (2007) reported that 27, 511, 892 people lived (14, 049, 594 males and 13, 462, 298 females) in Southwest, Nigeria. It has two distinct seasons which are: rainy season (April-October) and dry season (November-March). The temperature of the zone ranges between 21 and 28 degree centigrade (°C) with high humidity of 77 percent. Hence, crops and livestock production are done with little problems in the area. The major occupation of the people is agriculture. The other occupations include trading, driving, carpentry, etc. The official language is English, while the major informal language for communication in this region is Yoruba, which has different dialects. The choice of the selected states is due to the following. Lagos state; (i) was reported as the most hit and is the economic hub of the region (ii) High number of vegetable farmers with several flooded areas useful for the production of vegetable farmers especially during the non-rainy sessions Osun state; (i) Third most hit state in the regions of the COVID-19 pandemic and one of the economic hubs of the region (ii) Highest number of vegetable farmers with several flooded areas useful for the production of vegetable farmers especially during the non-rainy sessions Ekiti State (i) this state has been reported as the least hit and relative economic activities hub of the region (ii) Moderate number of vegetable farmers with highest number of irrigated vegetable farming

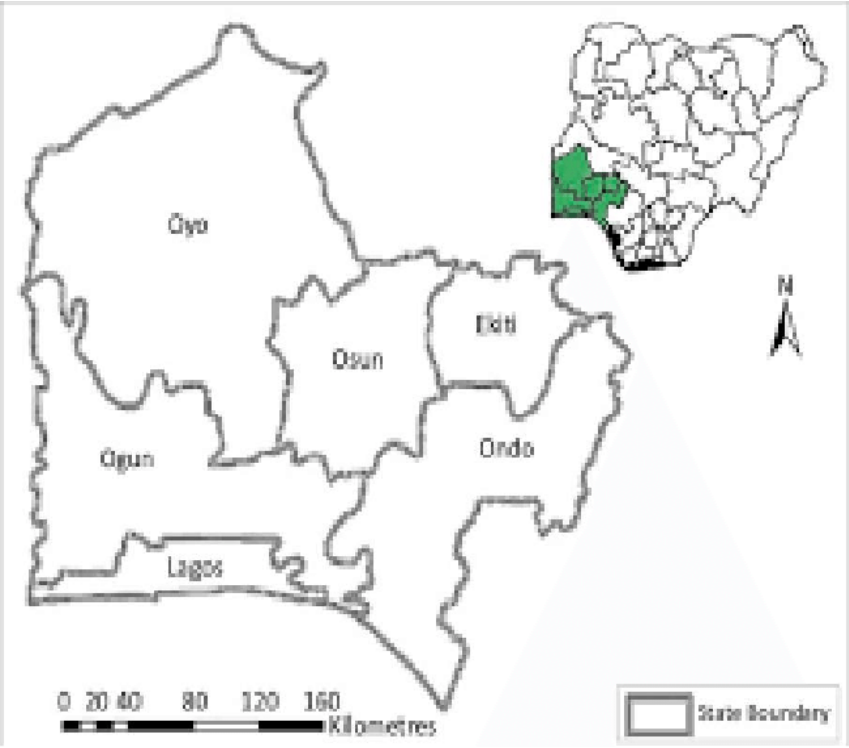

Figure-1. Map of Nigeria showing the Southwest States.
Source: *article.sapub.orgsors*

Sampling Technique

A multi-stage sampling technique was employed to select respondents for the study. There are six(6) States in South West of Nigeria, namely Ondo, Osun, Ekiti, Ogun, Lagos and Oyo. At the first stage, three (3) States were randomly selected (Osun, Ekiti and Lagos) out of the six (6) States. In the second stage, three (3) Local Government Areas (regions renowned for their vegetable farming) were randomly chosen from each of the states that had been chosen. A total of two (2) communities from each Local government area were chosen at random for the third stage. During the final stage, a random selection of fifteen (15) farmers in each community was taken. In all, a total of two hundred and seventy (270) respondents were selected for the study.

Data Analysis

Data for analysis were generated primarily using interview scheduled and structured questionnaires administered to two hundred and seventy (270) respondents selected for the study.

Analytical Technique

Using both descriptive and inferential statistics, the study's data were examined. Descriptive statistics like mean, percentages, and frequency distribution were used to evaluate Objectives I and IV. Using budgetary analysis, objective II was examined. With the help of (OLS) regression, objective iii was examined.

Model Specification

The gross margin analysis was used to estimate the profitability of vegetable production across several production scenarios. According to previous research, gross margin is the difference between total revenue (TR) and total variable cost (TVC). According to previous research, the bigger the gross margin, the higher the profit earned by vegetable producers. As a result, the analyses' mathematical notation is shown below:

GM = TR - TVC

GM stands for gross margin,
TR for total revenue,
and TVC for total variable cost. (these are the expenses incurred in production that does not depend on the level of output). These include costs of chemical, fertilizers, labour, and seeds.
Pq =Price of the Vegetable per kg,
q Pcm =Market price of variable input.

Also, the Net Revenue (NR) was calculated using the formula as follows:
NI= TR-TC

The net income model is expressed as below:
TC= TFC+ TVC
NI= TR-TC

Cost Benefit Ratio = TR/TC

Where;
NI=Income in Naira/ha
TR=Total Revenue in Naira/ha
TC= Total Cost
TFC = Total Fixed Cost in Naira/ha
TVC = Total Variable Cost in Naira/ha
TVC = Gross Margin in Naira/ha.

Ordinary Least Square Regression Model (OLS)

The OLS regression was used to determine factors influencing vegetable

production as applied in Fakayode *et.,al.* (2011).

The model is specified as:

$Y = f(\beta X + \mu i)$ … … . . (1)

Where:

Yi = Total farm output in kilogram

β = a vector of estimated coefficient of the explanatory variables

X = a vector of explanatory variables

Ui = disturbance term explicitly

The model is specified as:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \mu i$ …… (2)

where:

Y= Total farm output in kilogram

The explanatory variables used in the analysis are:

X_1 = Age (years)

X_2 = Marital status

X_3 = Household size (number of persons in the household)

X_4= Educational status

X_5 = Farm size (hectares)

X_6 = Farming experience (years)

X_7 = Times of extension visit (years)

X_8 = Membership of cooperative (Yes = 1, No = 0)

X_9 = Access to credit (Yes = 1, No = 0)

X_{10} = Marital Status (Married=1; Otherwise = 0

X_8 = Cost of fertilizer in Naira

X_9 = Cost of seeds in Naira

X_{10} = Cost of Chemicals (herbicides and pesticides) in Naira.

Multiple Linear Regression analysis:

The use of Multiple regression analysis to measure the causal effects of the predictors on dependent variables. The study explores the Farmers' specific characteristics and were modelled as determinants of the technical efficiency to comprehend how these characteristics influence the level of efficiency of the Vegetable farmers in each production scenarios:

Multiple linear regression analysis is modelled as follows:

$$Y = f(X_1, X_2, X_3, X_4, X_5, \ldots . X_8) + \epsilon_i \quad (1)$$

Where Y = Technical Efficiency (derived from DEA Model)

where,

X_1 =Sex dummy variables (male1 otherwise female =2)

X_2=Age (years)

X_3 =Educational level (years)

X_4= Marital Status (married=1 and 0 otherwise)

X_5=Household size (number)

X_6=Farm size (Hectares)

X_7 =Secondary occupation

εi=error term

Ordinary Least Square (OLS) approach was used as an estimation technique.

Result and Discussion

Socio-economic characteristics

Table 1 shows that vegetable production is gender dependent given that majority of the farmers were male (67%) and the remaining ones were females, implying that males were more involved in vegetable production enterprise than their female counterparts. The results revealed that majority (41.9%) of the famers were between 41 and 50 years of age, out of which male farmers were 35.2% and female vegetable farmers were 6.7%. By implication, the result depicts that vegetable farmers are relatively young, active and have agility to carry out farming activities and the

mean age is 42 years, which simply implies that the vegetable farmers in this region were still in an era when they can work. The findings imply that most respondents were in their middle years, falling within the Food and Agriculture Organization's stated age range of 30--50 for agricultural productivity (FAO, 2019).The results reveal that majority of the respondents (64.1%) were married while single, widowed and divorced respondents are (16.7%), (6.3%) and (12.9%) respectively. This is an indication that Married people dominated the activities in the study region. The marital status of a farmer may have a substantial impact on production decisions, according to Omolehin *et al.* (2007). The majority of respondents, it was discovered by the results, were married. They believed that married individuals were most likely to have the best capacity in traditional African society, which would result in higher output/income. The result showed that majority of the farmers were fairly educated with 22.2%, 25.2% and 19.6% having primary, secondary and tertiary education respectively. This means that the farmers had minimum level of education that could enable them to adopt and search for the latest innovation and agricultural technology in vegetable production. This is in agreement with the findings of Akinbile (2003), who reported that educational level of respondents enhances their comprehension of technical information and hence influence their profitability and production.

The result further revealed that majority (50%) of the respondent had a farm size between 2.5ha and 4 ha out of which male vegetable farmers were (37.4%) and about (12.3%) were female. About 38.1% of them had a farm size less than 2 ha, while 11% had between 4.5ha and 6ha, with the average mean farm size put at 3 hectares, this implies that production could be improved upon as 3 hectare per average household of 5 persons is on the low side. The result is similar to that of Apata *et al.* (2011), who posited that subsistence farmers play an important role for food security with an average farm size ranges between 1-3 hectares. Since the majority of respondents have farm holdings of less than 3 hectares, it means that these farmers cannot achieve economies of large-scale production. Small farm size is an impediment to agricultural mechanization because using farm machineries like tractors to control weeds will be difficult.

The results revealed that majority (41.9%) of the respondent had been engaged in vegetable production for less than 10 years. Also, about (5.2%) of the respondent had farming experience between 21and 30 years, only (11.5%) had 11 years and above as farming experience, while about (41.5%) of the respondent had engaged in vegetable production for 31 years and above. According to Adebayo (2006), the longer a person stays on a particular job, the better the job performance tends to be.

The result further showed that majority (86%) of the vegetable farmers stated they had been refused access to credit facilities for their farming operations in the study region. About 63.6% of vegetable farmers were male, compared to about 23.4% of female farmers

without recourse to credit. This suggests that the targeted vegetable producers in the study area have very limited access to credit facilities or that those facilities are most likely not reaching them. This finding is not encouraging because it raises the possibility that the farmers in the study region will produce less and make less money if they have restricted access to credit. Thus, Okoh *et al.* (2015), found that the major factors responsible for decline of production and profitability are inadequate credit facilities and low capital. Ajah *et al.* (2017) stated that limited access to credit perpetuates poverty and low quality of life among farmers who may wish to adopt more profitable innovations.

Table 1: Socio-economic characteristics of the respondents

Variables	**Male**	**Percentage**	**Female**	**Percentage**	**Mean**
Age(Years)					
01 – 30	15	5.6	28	10.4	
31 – 40	5	1.9	14	5.2	
41 – 50	95	35.2	18	6.7	42
51 – 60	38	14.1	15	5.6	
>60	42	15.6	0	0	
Marital status					
Married	149	55.2	24	8.9	
Divorced	22	8.1	13	4.8	
Widowed	17	6.3	0	0	
Single	7	2.6	38	14.1	
Level of Education					
No formal	68	25.2	21	7.8	
Peimary	60	22.2	0	0	
Secondary	28	10.4	40	14.8	
Tertiary	39	14.4	14	5.2	
Farm size(ha)					
<2	76	28.1	27	10	
2.5 – 4	101	37.4	34	12.6	
4.5 – 6	18	6.7	14	5.2	
Farming Experience					
<10	78	28.9	35	13	
11 – 21	72	26.7	40	14.8	
21 – 31	14	5.2	0	0	
>31	31	11.5	0	0	
Access to credit					
No	169	62.6	63	23.4	
Yes	26	9.6	12	4.4	

Source: Field survey, 2022.

Estimated costs and returns on vegetable production during and after covid-19 in the study area

According to the findings of the profitability analysis (Table 2), the study area's Total Variable Cost (TVC) per hectare for vegetable output before and after COVID-19 was N51,239.45 and N58,486.7, respectively. The majority of the costs incurred during vegetable production in the study region are comprised of the expenditure used in the production of vegetable in the study area. Among the variable costs recorded by the vegetable producers, land clearing recorded the highest cost during covid-19 as ₦12, 514.25 representing 17% per hectare of the overall cost of production. Additionally, after COVID-19, plowing expenses accounted for the highest variable cost paid in the production of vegetables, totaling 29.3%. From the results, the net farm income realized by a farmer during and after covid-19 accounted for ₦124,393.9 and ₦258,587.3 per hectare respectively. The gross margin analysis revealed a value of ₦146,219.8 and ₦270,374.4 per hectare during and after covid-19 respectively. The positive values obtained during and after Covid-19 indicated that In the study region, growing vegetables is a successful business.

The revenue generated by the cultivation of vegetables in the study region is not significantly different from the revenue generated by the cultivation of a different exotic vegetable (watermelon) in the states of Ekiti and Borno, respectively. In Ekiti State, according to Ajewole (2015), the gross margin for vegetable production was N138,044.22 per hectare, while in Borno State, according to Ibrahim (2011), the gross margin for vegetable production was N105,002.95 per hectare. It was discovered that the yield on invested naira was 1.70 and 3.68 during and after COVID-19, respectively. This means that during COVID-19, a farmer in the study area earned N1.70K in profit for every N1 invested in vegetable produce, while the area also saw a return of N3.68K after COVID-19. The Benefit-to-Cost Ratio of ₦2.85 and ₦4.6 during and after covid-19 also indicate that for every one naira spent ,₦2.85 and ₦4.6 will be realized as revenue respectively and so farmers in the region can go on with production of vegetable.

Gross Margin (GM) = TR –TVC (During Covid-19)
= ₦197,459.20 -₦51,239.45
= ₦146,219.80.

Gross Margin (GM) = TR – TVC (After Covid-19)
= ₦328,861.10 – ₦58,486.70
= ₦270,374.40

Therefore,

Benefit Cost Ratio (BCR) = Benefit/Cost (During Covid-19)
= ₦146,219.80/ ₦51,239.45
= ₦2.85.

Benefit Cost Ratio (BCR) = Benefit/Cost (After Covid-19)

=₦270374.40/₦58,486.70

=₦4.6.

Also,

Return on Investment = Net Return/Total Cost (Before Covid-19)

= ₦124,393.90/₦73065.29

=₦1.70.

Return on Investment = Net Return/Total Cost (After Covid-19)

=₦258,587.30/₦70273.78

=₦3.68

Table 2: Estimated Cost and Return of Vegetable Production during and After Covid-19

Description	During Covid-19 Lockdown	% of Total Cost	After Covid-19 Lockdown	% of Total Cost
Variable Cost				
Land Clearing	₦125,14.25	17.1	₦15,354	21.8
Ploughing	₦15,800	21.6	₦20,580.5	29.3
Chemical Application	₦2400	3.3	₦3,000	4.3
Fertilizer	₦5,000	6.8	₦4,500	6.4
Herbicides	₦7600	10.4	₦8,402.05	12
Transportation	₦5,625.2	7.7	₦4,800	6.8
Seed	₦2,300	3.1	₦1,850.2	2.6
Total Variable Cost	**₦51,239.45**	70.1	₦58,486.7	83.2
Fixed Cost				
Cutlass	₦3,800	5.2	₦1,200	1.7
Hoe	₦3,250.5	4.4	₦890.5	1.3
Depreciation on Knapsack Sprayer	₦4,850	6.6	₦6,200	8.8
Depreciation on Wheelbarrow	₦8,000.15	10.9	₦1,098.5	1.6
Depreciation on Watering Can	₦1,925.19	2.6	₦23,98.08	3.4
Total Fixed Cost	**₦21,825.84**	29.9	₦11,787.1	16.8

Total Cost	₦73,065.29	100	₦70,273.8	100
Total Revenue	₦197,459.2		₦328,861	
Net Return	₦124,393.9		₦258,587	
Gross Margin	₦146,219.8		₦270,374	
Return to Investment	1.7		3.68	

Source: field survey, 2021.

Factors influencing profitability of vegetable during COVID-19 lockdown in the study area

Table 3 displays the results of the regression estimates for the variables influencing vegetable output in the study area during COVID-19 lockdown. The criteria used in the selection of the lead equation are economic, statistical and econometric criteria, which specifically considered t-ratio, F-value, R^2, Adjusted R a priori expectations and significance of the estimated coefficients. The R^2 value of 0.61 implies that 61.0% of the total variation in the quantity generated of vegetable produced. The regression estimates revealed that output (X_8), gender of the farmer (X_9), farmer's year experience (X_2), level of education (X_3), cost of labour (X_4) had a significant influence on the profitability of vegetables in the study region during COVID-19 Lockdown. The amount of output generated had a positive significant impact on vegetable farming profit and was statistically significant at 1%, meaning an increase in output of 1 kg would result in a 0.61 increase in profit. The likelihood of being a male vegetable farmer will result in an increase in profit by a coefficient of 47168.43. Gender of vegetable farmers had a positive association with vegetable output. The 7059.89 coefficient will result in a rise in profit. Farmers' years of experience in vegetable production had a positive association with profitability. Also, Education is significant at 1percent, which implies that a unit increase in years spent in formal education will bring about the coefficient of 29966.43 increase in profit from vegetable farming. Cost of labour had a positive significant on profit from vegetable farming. This implies that a naira increase in cost of labour will give rise to an increase in profit on vegetable production by the coefficient of 212661.70, the result showed that increase in cost of transporting vegetable from production point to the point of sale will bring about more than the respective increase in sale price which in turn generate a higher profit.

Table 3: Factors influencing profitability of vegetable production during COVID-19 lockdown

Variables	Coefficient	Standard error	P-value
Constant	-429212.1***	0.22	0.005
Farm size(X_1)	8155.88***	10575.89	0.000
Farming Experience(X_2)	7059.89**	7526.46	0.659
Level of Education(X_3)	29966.43**	89153.09	0.367
Cost of Labour(X_4)	212661.70*	21523.37	0.302
Household size(X_5)	22213.53	10430.65	0.782
Credit access(X_6)	-41022.19	1182.56	0.000
Transportation(X_7)	-146.56	11660.09	0.010
Output(X_8)	0.61**	70870.27	0.563
Gender(X_9)	47168.43**	94221.55	0.024
Age(X_{10})	3318.64	98.71	0.138
Marital status(X_{11})	-80358.28	0.02	0.014
R^2	0.61		

Prob > chi2 =0.000, Dependent variable: Profitability, Significant: ** represent 1% significant level, * represent 5% significant level.
Source: field survey, 2021

Factors influencing profitability of vegetable after COVID-19 lockdown in the study area

Table 4 shows that X_8, X_9, X_{11}, X_5 X_6 are significant variables that significantly influenced the profitability of vegetables after the COVID 19 Lockdown in the research area: quantity of output, farmer gender, marital status, family size, and access to credit. All of the postulated explanatory variables explained the variation in the respondents, according to the estimated adjusted R^2 of 0.92. The quantity of vegetable produce (output) is statistically significant at 1 percent level of probability, implying that a unit increase in kg of vegetable produce will increase the profit by the coefficient of 0.92. The result also showed that the coefficient of farmers' age has an inverse relationship on vegetable net return and it is significant at 1% level. According to this, the impact of respondent age on the profit of vegetables in the study region is lessened as respondent age increases. The result also indicated that if the farmer age is increased by 1 year, there will be a decrease of 38199.47 coefficient in his or her profit. Marital status is significant at 5% and positively correlated with the profit of vegetable farmers. The likelihood of being a married vegetable farmer increases the profit by a coefficient of 8595.20. Household size had a positive impact on vegetables profit, with a statistical significance level of 1%. The profit of vegetable farmers will rise by 95180.05 coefficient as family size rises. At a 5% level of probability, farmers' access to credit is significant and positively correlated with their profitability. This suggests that having access to credit will allow farmers to grow vegetables on a big scale, thereby increasing their profits.

Table 4: Factors influencing profitability of vegetable production after COVID-19 lockdown

Variables	Coefficient	Standard error	P-value
Constant	165092.6	132387.9	0.212
Farm size	51381.073	33084.7	1.553
Farming Experience	-452.84	1409.88	0.748
Level of Education	9428.46	10154.54	0.353
Cost of Labour	-0.01	0.09	0.942
Household size	5110.45***	898.15	0.000
Credit access	9518.05**	3792.05	0.011
Tranportation	-1024.726	1090.03	0.94
Ouput	0.92***	0.15	0.000
Gender	-231.65	1757.78	0.895
Age	-38199.47**	17647.9	0.031
Marital status	-8595.20**	3508.25	0.014
R^2	0.92		

Dependent variable: Profitability, Significant: ** represent 1% significant level, * represent 5% significant level.

Source: field survey, 2021

Technical efficiency estimates of vegetable farmers in different production scenarios

The study analyzes the data in line with the study objective to examine technical efficiency of vegetable farmers in each production scenarios. Hence, the Technical Efficiency Estimates of Vegetable Production in Different Production Scenarios were done using Constant Returns to Scale (CRS) and Variable Returns to Scale) as a measurement metrics for assessment. The estimation procedure used here is taken a cue from the study that postulated the significance of technical efficiency in resource-use allocation. The Technical efficiency under the Variable Returns to Scale (VRS) was revealed. Thus, the mean total technical efficiency (i.e. when TE = 1) during Pre-COVID period is 0.74. Similarly, during COVID-19 lockdown, the mean total technical efficiency (i.e. when TE = 1) is 0.77 and the mean total technical efficiency (i.e. when TE = 1) during Post-COVID is 0.79. Moreover, the results of Constant Returns to Scale (CRS) under Pre-COVID, During COVID and Post-COVID-19 were also revealed. Consequently, the mean technical efficiency in terms of Pre-COVID-19 is 0.68; during COVID-19 lockdown 0.77 and Post-COVID-19 is 0.79. The results also revealed a considerable inefficiency during Pre-COVID period and this suggests that some of the vegetable farmers were not operating at an efficient scale and improvement in the overall efficiencies could be attained if the vegetable farmers modified their scale of operations.

Table 5: Technical efficiency estimates of vegetable production in different production ucenarios using CRS and VRS Estimates

	Pre-COVID-19 Lockdown				COVID-19 Lockdown				Post-COVID.19 Lockdown			
Technical	**VRS**		**CRS**		**VRS**		**CRS**		**VRS**		**CRS**	
Efficiencies Score	***F***	***%***	***F***	***%***	***F***	***%***	***F***	***%***	***F***	***%***	***F***	***%***
0.5001-0.7000	36	40.0	31	34.4	33	36.7	27	30.0	25	27.8	17	18.9
0.7001-0.8000	22	24.4	32	35.5	16	17.8	32	35.6	28	31.1	29	32.2
0.8001-0.9000	13	14,4	12	13.3	12	13.3	10	11.1	7	7.8	12	13.3
0.9001-0.9999	10	11.1	8	8.9	13	14.4	8	8.9	9	10.0	32	35.6
1	9	68.1	7	3.9	16	79.8	13	4.3	21	73.3	0	0.0
Total	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**
Mean	0.74		0.68		0.77		0.82		0.77		0.79	
Median	1		1		1		1		1		1	
Standard Deviation	0.57		0.52		0.61		0.66		0.59		0.81	
Minimum Value	0.43		0.41		0.48		0.37		0.38		0.77	
Maximum Value	1		1		1		1		1		1	

Source: Computed from Field Survey 2021

Determinants of CRS technical efficiency of vegetable farmers under different production scenarios

The study revealed the results of the regression estimates for all the production scenario considered in the study; Pre-COVID, COVID lockdown and Post-COVID under CRS description. The results of these description indicated that in the Pre-COVID, there are six variables that had significant effects on technical efficiency of vegetable production in this scenario. These variables are age with a coefficient 0.00571 which is significant at 5%. This thus infers that an increase in the number of age vegetable farmers by 5% wills probable lead to a decrease in technical efficiency by 0.00571. Likewise, the variables of education, farm experience, hired labour, credit access and market access all had the coefficients significant at various levels. Education variable coefficient is 0.04160.006071 and significant at 1%, and this infers that as education increases, there is the likelihood of the vegetable farmers to increase technical efficiency by 0.41. Similarly, farm experience, hired labour, credit access and market access with their coefficients as 0.00217, 0.0316, 0.0417 and 0.0621, respectively.

Likewise the results of the analysis under CRS description during COVID lockdown indicated four variables had significant effects on the technical efficiency of the vegetable farmers during COVID lockdown. The results of these description indicated that during COVID-19 lockdown, credit access and hired labour that were significant during pre-COVID were not significant at this production scenario. The significant variables under this production scenario are age, education, farm experience, and market access all had the coefficients significant at various level. These four variables had significant effects on technical efficiency of vegetable production in this scenario. Age has coefficient of 0.0032 (5%), education 0.00412 (1%), farm experience 0.00712 (1%) and

market access 0.0451 (1%). This thus infers that an increase in the number of age of vegetable farmers by 5% will probable lead to a decrease in technical by0.0032. likewise, the variables of education, farm experience, and market access all had the coefficients significant at various levels. This thus infers that as the co-efficient of these variables increases, there is the likelihood of the vegetable farmers to increase technical efficiency by 0.0032, 0.00412, 0.00712 and 0.0415 respectively.

Table 6: Results of CRS estimates of vegetable production in different production scenarios

Variable	Pre-COVID	Marginal Effect	COVID Lockdown	Marginal Effect	Post-COVID	Marginal Effect
Constant	0.7532***		0.9426***		0.8158***	
	(0.274)		(0.627)		(0.474)	
HHsize	-0.0625	-0.0517	0.0236	0.0321	-0.0213	-0.1156
	(0.0278)		(0.0471)		(0.00528)	
Age	0.00571**	0.00715	0.0032**	0.0027	0.00372**	0.0712
	(0.0041)		(0.0021)		(0.0631)	
Education	0.0416***	0.06123	0.00412***	0.0063	0.00521***	0.0218
	(0.0518)		(0.0628)		(0.0427)	
Sex	0.6145	0.8145	0.7317	0.9963	0.8621	0.4373
	(0.5721)		(0.6317)		(0.5621)	
Farm experience	0.00217***	0.0071	0.00712***	0.0094	0.0413***	0.0037
	(0.0005)		(0.0052)		(0.0041)	
Hired Labour	0.0316**	0.0041	0.05126	0.0061	0.0241***	0.0273
	(0.00216)		(0.0731)		(0.0341)	
Credit access	0.0417***	0.0613	0.00895	0.0058	0.0672***	0.0502
	(0.0391)		(0.0218)		(0.0541)	
Market access	0.0621***	0.0621	0.00451***	0.0062	0.0372***	0.0267
	(0.0021)		(0.00612)		(0.0041)	
Log likelihood	29.84159		11.94586		18.6802	

Source: Computed from Field Survey
N= 270, Significant at ***,1% ** 5%

Conclusion

The study reveals that in Nigeria's southwest, vegetable production is profitable. It shows that the profitability of vegetables during the COVID-19 Lockdown was significantly influenced by the quantity of vegetables produced, the farmer's gender, his or her years of experience, and the cost of labor, while the profitability of vegetables after the COVID-19 Lockdown was significantly influenced by the farmer's gender, marital status, household size, and access to credit. The results also revealed a considerable inefficiency during Pre-COVID period and this suggests that some of the vegetable farmers were not operating at an efficient scale and improvement in the overall efficiencies could be attained if the vegetable farmers

modified their scale of operations. The preceding analysis has brought some findings that have implications for this research work. Based on these findings, the following recommendations were made to increase the profit from the production of vegetable by the farmers in the study area:

1. Because the study found that as vegetable farmers' age increases, their profit decreases across all production scenarios, a policy that focuses on ways to attract and encourage young people who are agile and strong to start growing vegetables will help to reduce unemployment since the production of vegetable in the study area is profitable.
2. Age, education, marital status, labour costs, household size, farm size, and access to credit facilities are just a few of the socioeconomic factors that greatly influence vegetable production and profit generation in the study region. It is important to give all of these serious consideration.
3. Given that this situation was seen in the study region, the government should support and provide women with the tools they need to produce vegetables in order to address gender disparities.
4. Farmers' perceptions of the COVID-19 lockdown across the research area should also be taken into account in order to avoid any reduction in vegetable output in the event of a future pandemic.
5. Availability and allocation of large farm size should be encouraged among farmers so as to enhance their participation in vegetable production activities for higher profit since majority of them still engage in small farm size in the study area.
6. Since the study found that education will allow farmers to adopt new technologies that will increase their ability to profit from their output, it should also be promoted among vegetable farmers in the study area.
7. In order to secure enough production and profit generation, the government should always permit free movement of vegetable producers from their farms to the market in the event of future occurrences.
8. The results also revealed a considerable inefficiency during - COVID period and this suggests that some of the vegetable farmers were not operating at an efficient scale and improvement in the overall efficiencies could be attained if the vegetable farmers modified their scale of operations.

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ASSESSMENT OF DISPARITY IN URBAN FOREST TREES STRUCTURAL ATTRIBUTES, BIOMASS AND CARBON SEQUESTRATION OF TWO SELECTED CITIES IN NIGERIA DUE TO INFLUENCE OF URBANIZATION

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Abstract
Urban forests are known for ecosystem services which serve the people's needs and reservoirs atmospheric carbon. This study assesses urban forest trees diversity, biomass and carbon sequestration's potential in two selected cities: Ikeja and Abeokuta in southwestern, Nigeria. All trees with diameter at breast height (dbh) ≥ 10 cm were identified, dbh measured and their frequencies recorded. A total of 892 and 977 individual trees were distributed into 17 and 20 families with 26 and 38 tree species for Ikeja and Abeokuta respectively. Shannon-Wiener diversity index, maximum diversity index, species evenness computed for Ikeja were 2.74, 3.18 and 6.79 and for Abeokuta were 6.88, 0.403 and 0.461 respectively. The total volume estimated for these cities were 1350.34m^3 and 1971.75m^3 for Ikeja and Abeokuta respectively. The total estimated above-ground biomass (AGB), below-ground biomass (BGB) and carbon stock for trees in Ikeja were 1375.41 tons, 275.08 tons and 825.25 tons respectively and for Abeokuta 1939.10 tons, 387.82 tons and 1163.46 tons were obtained respectively This is an indication of the level of carbon storage differences in the two cities. Urban forest conservation and restoration should be paramount to government at all levels. This should lead to the formulation of policies on the conservation, planting and creation of awareness on the significance of urban forests for ecosystem services and function in a sustainable manner.

Keywords: Correlation coefficient, Carbon storage, Ecosystem services, Environmental sustainability, Restoration potentials, Urban forest conservation, Urban expansion

Introduction

Green spaces are essential to the urban ecosystem and urbanization development especially in developing countries of the world. Urban forests are an important component of urban area as they provide many environmental and social services that contribute to the quality of life in cities in terms of social, physical, economic and environmental sustainability of the urban dwellers (Fuwape and Onyekwelu, 2011). Urban forests in most cities of Nigeria are gradually becoming reduced as a result of urbanization, human activities, thereby posing adverse effects (Agbelade *et al.,* 2022). Urban forest ecosystems are vital in reducing the likelihood of pests and diseases, mitigate climate change, acid rain, and air pollution (Konijnendijk *et*

al., 2004; Abino *et al.,* 2014). Urban trees, parks, gardens, woodlots/lands are categorized as green spaces that mitigate high temperature, decrease pollution, water run-off and soil erosion, increase aesthetics and quality of places, provide a place for recreation, education and learning. Trees reduce CO_2 in the atmosphere and mitigate urban heat island directly and indirectly.

Urban forests biodiversity could be influenced by the way and manner of management in conserving ecosystems functions and these can be managed properly during constructions of infrastructures (Agbelade *et al.,* 2016; Boadi *et al.,* 2017). In particular, information is required on the tree's spatial distribution within the city. Urban forests trees are managed spatially by individual, government city managers and environmental health workers using government policies for environmental development of green spaces (Woldegerima *et al.,* 2017; Agbelade *et al.*, 2022). Urban forest planner can easily locate areas with dense trees and areas with no trees that require tree planting, detect diseases on urban trees, discovered trees that are hazardous to human and infrastructures, measure the growth of the trees and assess the tree canopy benefits and many other uses.

The ecosystem benefits and services provided by trees contribute to urban function and tree species diversity provides the resistance and resilience necessary to ensure long-term provision of benefits and ecosystem services (Morgenroth *et al.,* 2015; Koricho *et al.,* 2020). Tree species diversity has greater impact on biomass accumulation which determines carbon sequestration and mitigation of harsh climatic conditions (Adekunle *et al.,* 2014; Agbelade and Onyekwelu, 2020). Urbanization would threaten biodiversity; reduce urban forests ecosystem functioning and in turn hampered ecosystem services to the environment and human which depend on them for survivor.

Ecosystem services such as carbon sequestration, water purification, food production, beautification purposes, medicinal products, recreational activities, nutrient cycling and soil erosion prevention are adequately performed by urban forests cover. These could influence the performance of urban forest biodiversity and ecosystem services from the home garden, street trees, avenue tree, parking lots, woodlands, parks and gardens.

Researchers have indicated different importance of urban forest such as provision of goods, services, and serve as gene bank and biodiversity reservoir, avenue for sustainable environment and mitigation of harsh climate change (Agbelade *et al.*, 2017; Agbelade and Onyekwelu, 2020; Moussa *et al.,* 2020). The sustainability of urban forest depends solely on the management level with enhance policy formulation and implantation strategy. There are no forms of information in relation to biomass and carbon storage about green infrastructures in these two cities in Nigeria. There is therefore the need for the determination of disparity between the structural attributes of urban forest trees, biomass and carbon sequestration ability of these mega cities. In order to sustainably manage urban forests space, there is need for proper, accurate and readily available information on the level

of biomass, carbon sequestration and carbon dioxide removed from the atmosphere. Current and accurate information on urban forests biomass in the country could help raise the profile of urban forest carbon credits and increase the potentials for green economy in Nigeria.

Methodology

Study area

This study was conducted in two major cities in Nigeria: Ikeja, Lagos State and Abeokuta, Ogun State (Figure 1). The two cities are located in the rainforest vegetation zone in south-western region of Nigeria. Ikeja is situated between the 06°35'80''N - 06°36'09''N and 03°20'99''E - 03°21'16''E co-ordinates, with average annual temperature of 25°C to 34°C. The metropolis occupies an area of about 1,171 km² (452.23 sq m). The heaviest rain fall occurs in April to July and the lesser rainy season is between October and November with average annual rainfall of 1783 mm. There is relatively brief dry season from December to March. Abeokuta lies between the 07°10'547''N - 07°18'407''N and 03°23'06''E - 05°09'97''E coordinates. Abeokuta is covered predominantly by rain forest, with an average temperature of 26.0 °C, with land area of 16,762 km² with average annual rainfall of 1,340 mm. Ogun State has wide area of undulating lowlands belonging to the coastal sedimentary rocks of western Nigeria.

Methods of data collection

Tree inventory was conducted in the two cities to obtain data for analysis on species diversity and biomass. The main streets in both Ikeja and Abeokuta were selected for data collection in various sections of the city. All woody plants in the selected city with diameter at breast height (DBH) ≥ 10 cm were measured and identified. The following tree data were collected; diameter at breast height using girth tape, diameters over bark at the base, middle, merchantable height and total height at 1.3m above ground level using a Spiegel Relaskop (Agbelade and Onyekwelu 2020). Biomass expansion factor (BEF) was used for the quantitative analysis of biomass and carbon stock potential of the two selected cities.

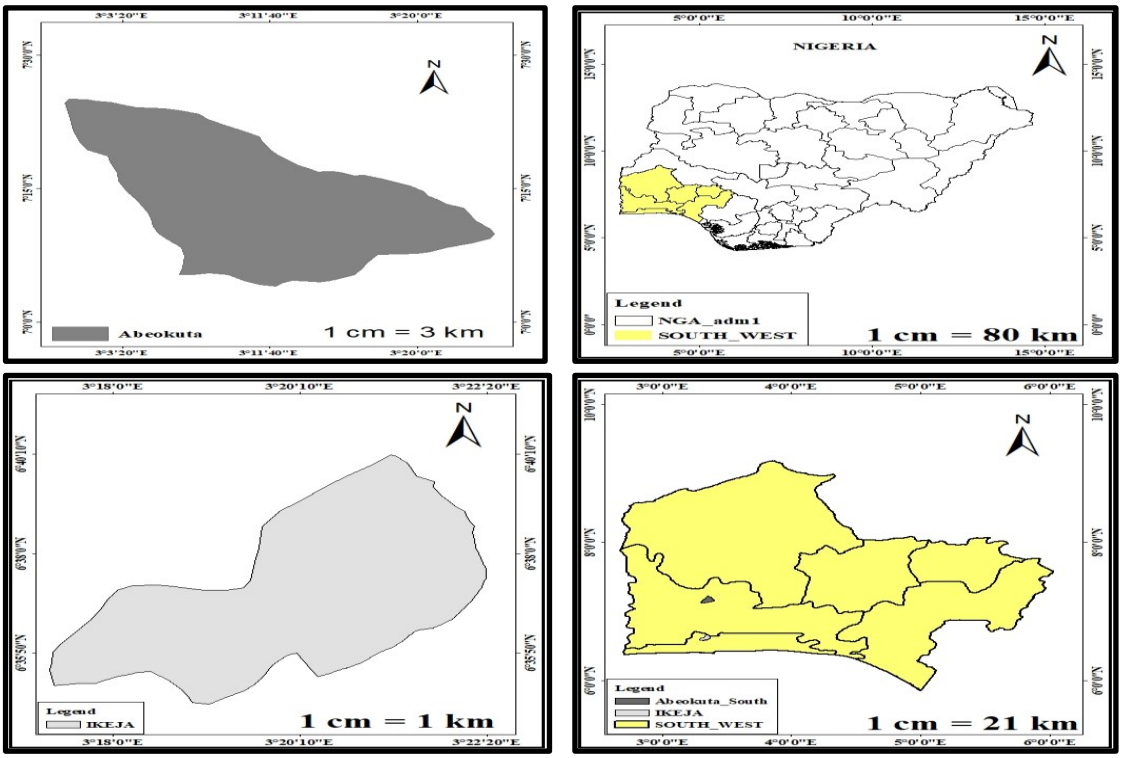

Figure 1: Study area map

Data analysis for urban forest species diversity

Species Relative Density (RD)% used to determine species relative distribution was computed using:

$$RD\% = \frac{ni}{N} x\ 100 \quad (1)$$

Where: n_i = number of individuals of species i; N = total number of all individual trees of all species in the sampled street of the city.

Species Relative Dominance (RDo) was estimated using:

$$RDo = \left(\frac{\sum Ba_i\ x\ 100}{\sum Ba_n}\right) \quad (2)$$

Where: Ba_i = basal area of all trees belonging to a particular species *i*; Ba_n = basal area of all individual tree.

Importance Value Index (IVI) of each species was computed with the relationship:

$$IVI = \left(\frac{RD + RD_o}{2}\right) \quad (3)$$

Species diversity index (H') was computed using the Shannon-Wiener diversity index below:

$$H' = -\sum_{i=1}^{s} Pi\ In(Pi) \quad (4)$$

Where: S = total number of species in the sampled street of the city; p_i = proportion of S made up of the ith species; ln = natural logarithm.

Shannon's maximum diversity index (H_{max}) was calculated using:

$$H_{Max} = Ln\ (S) \quad (5)$$

Where: H_{max} S= total number of species in the sampled street of the city.

Species evenness in each plot was determined using Shannon's equitability (E_H), which was obtained using:

$$E_H = \frac{H'}{H_{Max}} = \frac{\sum_{i=1}^{s} P_i Ln\ P_i}{Ln\ (S)} \quad (6)$$

Forest structure

The basal area of each tree in the city was calculated using

$$BA = \frac{\pi D^2}{4} \quad (7)$$

Where: BA = Basal area (m^2), D = Diameter at breast height (cm) and л= pie (3.142). The total basal area for the plot was obtained by adding all trees basal area in the sampled streets of the city.

Volume of individual trees were estimated using

$$V = \pi h \frac{Db^2+4(Dm^2)+Dt^2}{24} \quad (8)$$

Where: V = Tree volume (m^3), π = 3.142, h = tree height (m) measurement, Db, Dm and Dt = tree cross-sectional area at the base, at the middle and top of merchantable height respectively.

Biomass and carbon stock

In determining the total carbon (TC) stocks, estimation of AGB and BGB were computed. Biomass expansion factor (BEF) of 1.74 was used to estimate tree above ground biomass for tropical rainforest (Brown and Lugo, 1992). This was multiplied by volume over bark (m^3 ha^{-1}) and wood density (kg).

$$\text{AboveGround Biomass (AGB)} = \text{BEF} * \text{VOB} * \text{WD} \quad (9)$$

Where, BEF = Biomass expansion factor; VOB = Volume over bark (m^3); WD = Wood density (kg). Wood density for tree species was acquired from Global Wood Density Database (https://db.worldagroforestry.org/wd). Arithmetic mean of (0.600 g/cm^3) for a tropical African forest was used for species that were not found in the database following Chave *et al.* (2005). The carbon stock of the urban forests was determined by a fraction of 50% of biomass.

$$\text{AGC} = \text{AGB x } 0.5 \quad (10)$$

Thus, above ground carbon (AGC) was calculated as a conversion factor of 0.5 multiplied by AGB (Chave *et al.,* 2005).

$$\text{BGB} = \text{AGB x } 0.2 \quad (11)$$

Where below-ground biomass was computed as 20% of AGB using synthesis of global data and conservative ratio shoot-to-root biomass of 5:1 basis (Meragiaw *et al.*, 2021).

$$\text{TC} = \text{AGC} + \text{BGC} \quad (12)$$

The estimation of carbon content in BGC is the same as that of AGC equation 12. Total carbon stock (TCS kg ha^{-1}) was calculated by summing up the carbon stock of AGC and BGC following Pearson *et al.* (2007).

Results

Phytosociological characteristics, diversity and biomass estimation

Biodiversity indices and growth variables obtained for tree species for urban forests in the two cities studied were calculated as indicated in (Table 1 and 2). Shannon-Wiener diversity index of 2.74 and 3.18, maximum diversity index of 6.79 and 6.884, species evenness of 0.403 and 0.461 were computed for Abeokuta and Ikeja respectively. A total of 892 and 977 individual trees were distributed into 26 and 38 species for Ikeja and Abeokuta respectively. The highest species relative density for Ikeja was *Polyalthia longiflora* (14.24 %) followed by *Terminalia mantaly* (13.34%) and *Roystonea regia* (12.22%) while *Milicia excelsa* (0.11%) was the lowest for the city. The highest relative dominance in Ikeja was *Milicia excelsa* (28.53%) followed by *Roystonea regia* (10.13%) and *Delonix regia* (7.63%) while *Morinda lucida* (0.39%) was the lowest for the city. In Abeokuta urban

forest high species relative density of were obtained for *Mangifera indica* (10.44%), *Gmelina arborea* (7.98%) and *Ficus sur* respectively (7.37%) while *Vitex ferruginea* (0.10%) had the least. The highest relative dominance was *Khaya grandifolia* (12.12%) followed by *Mangifera indica* (9.45%), and *Gmelina arborea* (8.16%) while *Psidium guajava* (0.19%) had the lowest value. The total volume of trees estimated for the two cities were 1350.34 m^3 and 1971.75 m^3 for Ikeja and Abeokuta respectively. The total estimated above-ground biomass (AGB), below-ground biomass (BGB) and carbon stock for trees in Ikeja were 1375.41 tons, 275.08 tons and 825.25 tons respectively while 1939.10 tons, 387.82 tons and 1163.46 tons were estimated for Abeokuta respectively.

Tree species abundance in the two metropolitan cities

In Ikeja, the species with the highest species density were *Polyalthia longiflora* (127), *Terminalia mantaly* (119), *Roystonea regia* (109) and *Terminalia catappa* (102) while in Abeokuta *Mangifera indica* (102), *Polyalthia longiflora* (81), *Gmelina arborea* (78) and *Ficus sur* (72) were the species with highest species density Figures 2 and 3.

Table 1: Urban tree species diversity and structure in Ikeja

Species name	Family	BA	VOL	RD	RDo	IVI	H'	AGB	BGB	TCS
Anacardium occidentale Linn	Anacardiaceae	0.08	20.68	1.35	1.68	1.51	0.06	16.17	3.23	9.70
Annona muricata L.	Annonaceae	0.03	3.38	0.34	0.59	0.46	0.02	2.35	0.47	1.41
Azadirachta indica (A. Juss)	Meliaceae	0.37	85.00	1.68	7.50	4.59	0.07	107.67	21.53	64.60
Bixa orellana Linn.	Bixaceae	0.03	4.41	0.11	0.66	0.39	0.01	2.86	0.57	1.72
Casuarina equisetifolia Linn.	Casuarinaceae	0.13	40.10	3.03	2.68	2.85	0.11	64.12	12.82	38.47
Citrus sinensis (L) Osbeck	Rutaceae	0.03	3.85	1.79	0.54	1.17	0.07	5.23	1.05	3.14
Cocos nucifera (Linn)	Palmae	0.07	13.17	3.48	1.32	2.40	0.12	14.14	2.83	8.48
Delonix regia (Boj.) Raf.	Fabaceae	0.38	90.58	2.58	7.63	5.11	0.09	94.57	18.91	56.74
Eucalyptus citriodora F. Muell.	Myrtaceae	0.05	16.71	2.91	1.04	1.98	0.10	24.13	4.83	14.48
Ficus benjamina Linn.1767	Moraceae	0.07	17.39	4.26	1.38	2.82	0.13	15.10	3.02	9.06
Ficus exasperate Vahl.	Moraceae	0.03	6.41	0.78	0.64	0.71	0.04	3.84	0.77	2.30
Ficus sur Forssk. 1775	Moraceae	0.14	23.56	2.80	2.75	2.78	0.10	13.73	2.75	8.24
Gmelina arborea Roxb.	Lamiaceae	0.43	130.89	8.52	8.58	8.55	0.21	99.98	20.00	59.99
Leuceana leucocephala (Lam.) de Wit	Fabaceae	0.02	3.70	1.01	0.44	0.72	0.05	3.82	0.76	2.29
Magnifera indica Linn.	Anacardiaceae	0.19	51.01	5.83	3.91	4.87	0.17	53.25	10.65	31.95
Milicia excelsa (Welw.) C.C. Berg.	Moraceae	1.42	467.31	0.11	28.53	14.32	0.01	482.18	96.44	289.31
Morinda lucida L.	Rubiaceae	0.02	3.81	0.90	0.39	0.64	0.04	3.78	0.76	2.27
Moringa oleifera Lam.	Moringaceae	0.03	5.25	1.23	0.67	0.95	0.05	2.39	0.48	1.44
Newbouldia laevis (P. Beauv.) Seem.	Bignoniaceae	0.07	11.99	1.12	1.43	1.28	0.05	12.52	2.50	7.51
Pinus caribaea Morelet	Pinaceae	0.07	22.26	0.67	1.51	1.09	0.03	21.30	4.26	12.78
Polyalthia longiflora (Sonn.) Thwaites	Annonaceae	0.03	8.62	14.24	0.67	7.45	0.28	8.84	1.77	5.30
Roystonea regia (Kunth) O.F. Cook	Arecaceae	0.50	153.87	12.22	10.13	11.18	0.26	160.64	32.13	96.39
Senna siamea (Lam) Irwin & Barneby	Fabaceae	0.10	16.27	1.23	2.00	1.62	0.05	19.31	3.86	11.58
Terminalia catappa Linn.	Combretaceae	0.20	55.04	11.43	4.05	7.74	0.25	51.72	10.34	31.03
Terminalia ivorensis A. Chev.	Combretaceae	0.08	15.65	3.03	1.57	2.30	0.11	13.12	2.62	7.87
Terminalia mantaly H. Perrier	Combretaceae	0.38	79.44	13.34	7.63	10.48	0.27	78.65	15.73	47.19
		4.98	1350.34				2.74	1375.41	275.08	825.25

Table 2: Urban tree species diversity and structure in Abeokuta

Species name	**Family**	**BA**	**VOL**	**RD**	**RDo**	**IVI**	**H'**	**AGB**	**BGB**	**TCS**
Albizia zygia (DC.) J.F. Macb	Fabaceae	0.11	23.59	0.92	1.37	1.15	0.04	21.14	4.23	12.68
Alstonia bonnei De wild	Apocynaceae	0.23	51.26	0.41	2.90	1.65	0.02	33.45	6.69	20.07
Anacardium occidentale Linn	Anacardiaceae	0.28	54.88	2.25	3.58	2.92	0.09	42.93	8.59	25.76
Azadirachta indica A. Juss.	Meliaceae	0.53	135.52	3.17	6.75	4.96	0.11	171.66	34.33	103.00
Bombax costatum Pellegr. & Vuillet	Bombacaceae	0.10	24.53	0.20	1.29	0.75	0.01	14.90	2.98	8.94
Casuarina equisetifolia Linn.	Casuarinaceae	0.36	85.21	1.54	4.61	3.07	0.06	136.26	27.25	81.75
Cocos nucifera (Linn)	Palmae	0.05	15.16	1.94	0.67	1.31	0.08	16.27	3.25	9.76
Delonix regia (Boj.) Raf.	Fabaceae	0.05	9.79	2.15	0.58	1.36	0.08	10.22	2.04	6.13
Eucalyptus citriodora F. Muell	Myrtaceae	0.03	3.64	1.64	0.35	0.99	0.07	5.25	1.05	3.15
Ficus benjamina Linn.1767	Moraceae	0.49	96.75	5.94	6.30	6.12	0.17	84.00	16.80	50.40
Ficus exasperate Vahl	Moraceae	0.07	11.51	1.23	0.94	1.09	0.05	6.89	1.38	4.13
Ficus sur Forssk. 1775	Moraceae	0.14	35.09	7.37	1.80	4.58	0.19	20.45	4.09	12.27
Gliricidia sepium (Jacq.) Steud.	Fabaceae	0.07	19.11	4.40	0.94	2.67	0.14	22.74	4.55	13.64
Gmelina arborea Roxb.	Lamiaceae	0.63	167.17	7.98	8.16	8.07	0.20	127.70	25.54	76.62
Holarrhena floribunda (G. Don) T. Durand & Schinz	Apocynaceae	0.06	6.77	0.20	0.71	0.46	0.01	5.53	1.11	3.32
Hura crepitans L.	Euphorbiaceae	0.11	19.84	1.33	1.45	1.39	0.06	12.60	2.52	7.56
Khaya grandifoliola C.DC.	Meliaceae	0.94	331.31	1.23	12.12	6.67	0.05	320.52	64.10	192.31
Khaya senegalensis (Desr.) A. Juss	Meliaceae	0.38	97.83	0.31	4.84	2.58	0.02	112.00	22.40	67.20
Leuceana leucocephala (Lam.) de Wit	Fabaceae	0.03	11.27	2.66	0.41	1.54	0.10	11.63	2.33	6.98
Magnifera indica Linn.	Anacardiaceae	0.74	179.82	10.44	9.45	9.95	0.24	187.73	37.55	112.64
Margarita riadiscoidea (Baill.) G.L.Webster	Phyllanthaceae	0.06	8.14	0.20	0.72	0.46	0.01	10.91	2.18	6.55
Morinda lucida L.	Rubiaceae	0.02	3.24	2.15	0.20	1.18	0.08	3.22	0.64	1.93
Musanga cercropioides R. Br. & Tedlie	Urticaceae	0.25	47.88	1.13	3.27	2.20	0.05	20.08	4.02	12.05
Newbouldia laevis (P. Beauv.) Seem.	Bignoniaceae	0.08	17.43	1.94	1.03	1.49	0.08	18.20	3.64	10.92
Piptadeniastrum africanum (Hook. F.) Brenan	Fabaceae	0.04	9.85	0.10	0.57	0.34	0.01	10.97	2.19	6.58

Table 2 continued

Species name	Family	BA	VOL	RD	RDo	IVI	H'	AGB	BGB	TCS
Plumeria rubra L.	Apocynaceae	0.13	28.86	1.13	1.64	1.38	0.05	28.12	5.62	16.87
Polyalthia longiflora (Sonn.) Thwaites	Annonaceae	0.06	14.07	8.29	0.76	4.53	0.21	14.42	2.88	8.65
Psidium guajava L.	Myrtaceae	0.01	2.88	1.02	0.19	0.61	0.05	3.37	0.67	2.02
Pterocarpus erinaceus Poir	Fabaceae	0.03	4.94	0.20	0.36	0.28	0.01	6.36	1.27	3.82
Roystonea regia (kunth) O.F. Cook	Arecaceae	0.40	125.51	2.25	5.19	3.72	0.09	131.04	26.21	78.62
Senna siamea (Lam) Irwin & Barneby	Fabaceae	0.10	16.46	1.54	1.35	1.44	0.06	19.53	3.91	11.72
Spondias mombin Linn.	Anacardiaceae	0.18	31.22	2.15	2.36	2.25	0.08	21.29	4.26	12.78
Tectona grandis Lf.	Lamiaceae	0.33	117.72	5.32	4.18	4.75	0.16	125.56	25.11	75.34
Terminalia catappa Linn.	Combretaceae	0.14	19.56	5.73	1.74	3.73	0.16	18.38	3.68	11.03
Terminalia ivorensis A. Chev.	Combretaceae	0.12	29.19	1.94	1.58	1.76	0.08	24.49	4.90	14.69
Terminalia mantaly H. Perrier	Combretaceae	0.23	65.72	7.27	3.02	5.14	0.19	65.07	13.01	39.04
Vitex doniana Sweet	Verbenaceae	0.04	7.94	0.20	0.45	0.33	0.01	8.20	1.64	4.92
Vitex ferruginea Schumach. and Thonn.	Verbenaceae	0.17	41.07	0.10	2.16	1.13	0.01	46.03	9.21	27.62
		7.78	1971.75				3.18	1939.10	387.82	1163.46

Where BA= Basal area (m^2); VOL = Volume (m^3); RD = Relative Density (%); RDo = Relative Dominance (%); IVI = Important Value Index (%); H' = Shannon Wiener Diversity Index; AGC = Above-Ground Carbon (kg); BGC = Below-Ground Carbon (kg); TCS = Total Carbon Stock (kg).

Diameter and Height distribution

The tree diameter distribution in the two cities showed the presence of the highest number of individual trees in the small diameter class of 10 cm to 49.9 cm, while the lowest number of trees occurred between 50 cm to >90 cm diameter class. The diameter distribution of trees in each city followed inverted J distribution pattern (Figure 2). The height class indicated that 10.0 cm to 14.9 m has the highest number of individual trees in the two metropolitan cities. No tree was recorded for height class range of 1.0 m to 9.9m and 25.0 m to 34.9 m in Abeokuta while in Ikeja. height class range of 1.0 m to 4.9 m and 25.0 m to 29.9 m had no tree.

Correlation coefficient of the tree structure, diversity, biomass and carbon stock

The highest correlation coefficient values obtained between the Volume and logarithm volume, AGB and logarithm of AGB, logarithm of BGB, logarithm of TCS (0.999) were positive with significant differences existing among these variables in Abeokuta metropolitan city. The total carbon stock and logarithm of AGB, BGB, TCS had positive correlation coefficient values and indicated high significant level among all the variables (Table 3a). There exist very weak correlation coefficients between basal area and Shannon-Wiener diversity index and logarithm of Shannon-Wiener diversity index (Table 3a). In Abeokuta, there was positive linear relationship between the variables tested in the city. The highest correlation coefficient values were obtained between volume and logarithm of volume, AGB and TCS, AGB and logarithm of AGB, logarithm of Shannon-Wiener diversity index and logarithm of AGB, TCS, while the logarithm of BGB, TCS and logarithm of TCS indicated significant levels for these variables in Ikeja metropolitan city (Table 3b). Very weak correlations were obtained for Shannon-Wiener diversity index and logarithm of basal area, volume, AGB, BGB, TCS. It was also observed that weak correlation existed between volume and Shannon-Wiener diversity index in Ikeja.

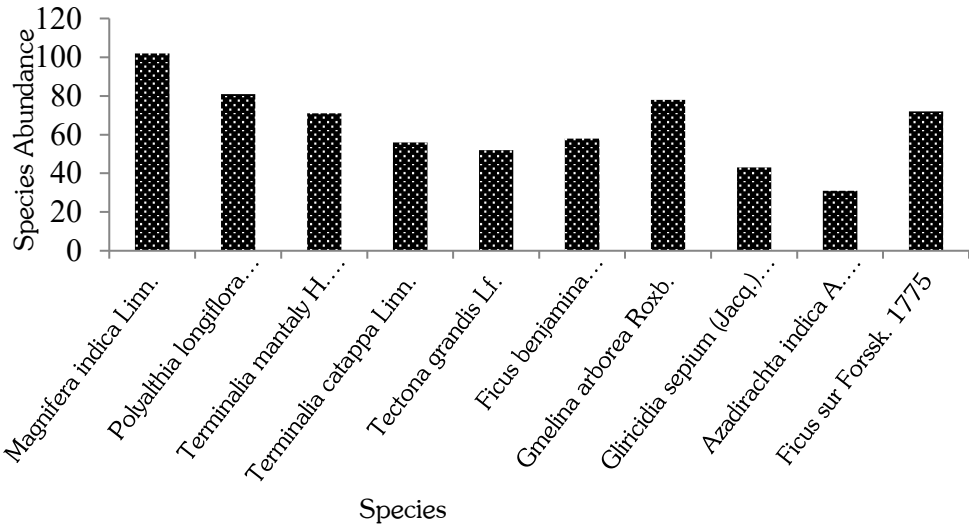

Figure 2: Ten most abundant species in Abeokuta

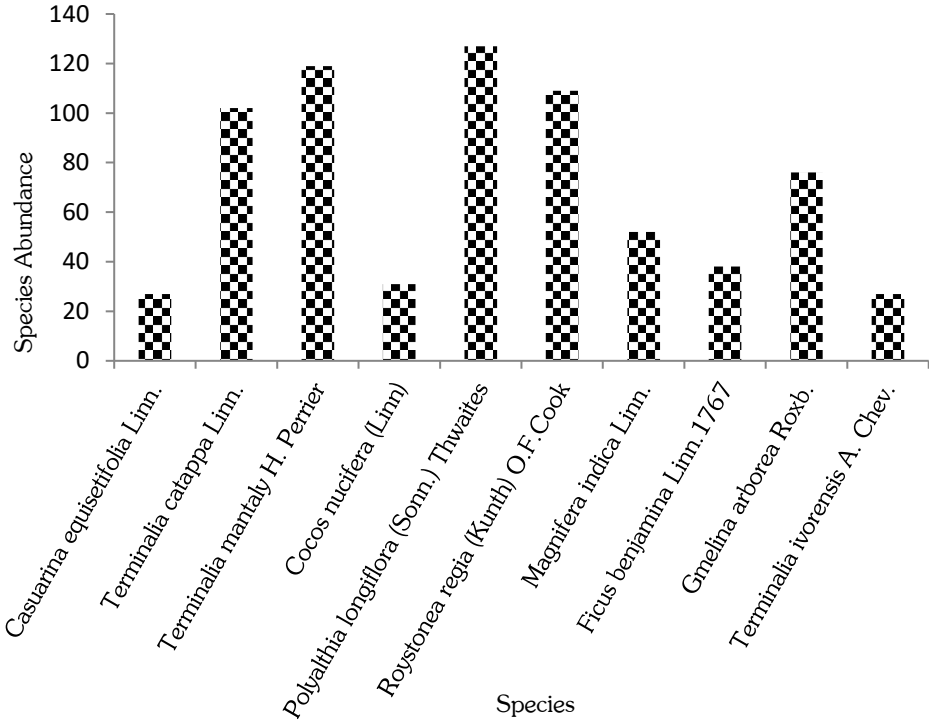

Figure 3: Ten most abundant species in Ikeja

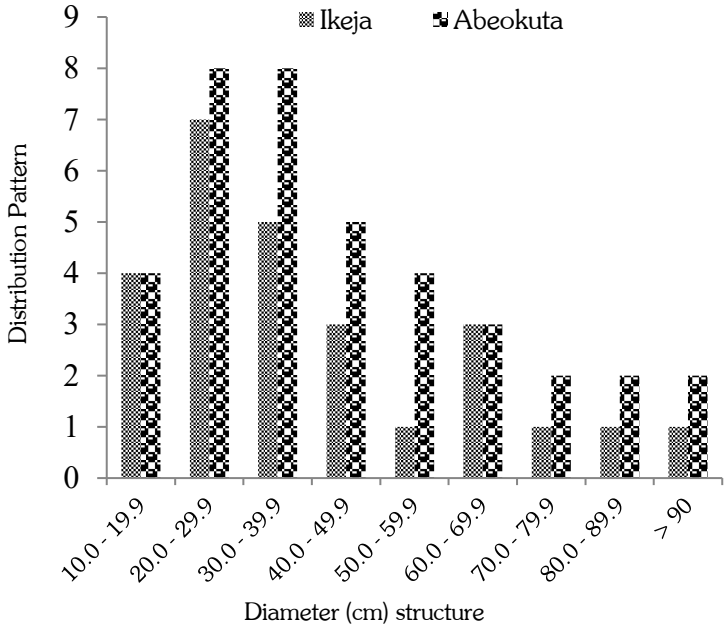

Figure 4: Diameter distribution pattern

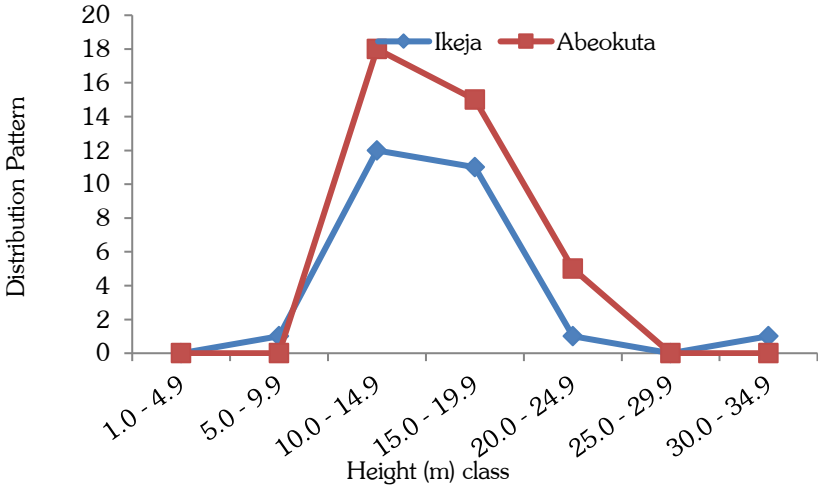

Figure 5: Height distribution pattern

	BA	Vol.	H'	AGB	BGB	TCS	LnBA	LnVol.	LNH'	LnAGB	LnBGB	LnTCS
BA	1.000											
VOL	0.976**	1.000										
H'	0.352*	0.391*	1.000									
AGB	0.934**	0.965**	0.392*	1.000								
BGB	0.934**	0.965**	0.392*	0.999**	1.000							
TCS	0.934**	0.965**	0.392*	0.999**	0.999**	1.000						
LnBA	0.999**	0.979**	0.364*	0.936**	0.936**	0.936**	1.000					
LnVol.	0.976**	0.999**	0.391*	0.965**	0.965**	0.965**	0.979**	1.000				
LnH'	0.352*	0.383*	0.995**	0.378*	0.378*	0.378*	0.363*	0.383*	1.000			
LnAGB	0.934**	0.965**	0.392*	0.999**	0.999**	0.999**	0.936**	0.965**	0.378*	1.000		
LnBGB	0.934**	0.965**	0.392*	0.999**	0.999**	0.999**	0.936**	0.965**	0.378*	0.999**	1.000	
LnTCS	0.935**	0.965**	0.392*	0.999**	0.999**	0.999**	0.937**	0.965**	0.379*	0.999**	0.999**	1.000

Table 3a: Correction matrix for tree structure, diversity, biomass and carbon sequestration in Abeokuta metropolitan city

BA=Basal area; Vol.=Volume; H'=Diversity index; AGB=Above-Ground biomass; BGB=Below-Ground biomass; TCS=Total carbon stock
Ln=Natural logarithm

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

	BA	Vol.	H'	AGB	BGB	TCS	LnBA	LnVol.	LNH'	LnAGB	LnBGB	LnTCS
BA	1.000											
VOL	0.873**	1.000										
H'	0.351*	0.357*	1.000									
AGB	0.764**	0.840**	0.344*	1.000								
BGB	0.765**	0.844**	0.342*	0.998**	1.000							
TCS	0.764**	0.840**	0.344*	0.999**	0.998**	1.000						
LnBA	0.965**	0.873**	0.333*	0.750**	0.748**	0.750**	1.000					
LnVol.	0.873**	0.999**	0.357*	0.840**	0.844**	0.840**	0.873**	1.000				
LnH'	0.762**	0.838**	0.348*	0.998**	0.997**	0.998**	0.748**	0.838**	1.000			
LnAGB	0.764**	0.840**	0.344*	0.999**	0.998**	0.999**	0.750**	0.840**	0.998**	1.000		
LnBGB	0.762**	0.838**	0.348*	0.998**	0.997**	0.998**	0.748**	0.838**	0.999**	0.998**	1.000	
LnTCS	0.762**	0.838**	0.348*	0.998**	0.997**	0.998**	0.748**	0.838**	0.999**	0.998**	0.999**	1.000

Table 3b: Correction matrix for tree structure, diversity, biomass and carbon sequestration in Ikeja metropolitan city

BA=Basal area; Vol.=Volume; H'=Diversity index; AGB=Above-Ground biomass; BGB=Below-Ground biomass; TCS=Total carbon stock
Ln=Natural logarithm

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Discussion

Tree species diversity and structure

The inventory of urban forest resources to determine the distribution of species density, abundance, and diversity has been widely used to characterize the forests structure of communities. Biodiversity indices are usually of importance in the determination of floristic diversity and abundance for assessing conservation status of urban forest in determining the ecosystem services. Urban trees offer ecosystem services and reduce the harsh environmental conditions connected to urban centres and climate change (Liu and Li 2012; Agbelade and Onyekwelu 2020).

The tree species encountered in the two cities are indigenous tropical hard wood and exotic trees associated with tropical rainforest ecosystems. This suggests that urban forests have been infiltrated with exotic tree species. The dominance of exotic species (*Terminalia mantaly, Delonix regia, Ficus benjamina* and *Polyalthia longiflora*) is crucial for the preservation, beautification of urban forests landscapeand which indirectly ensures that the urban forests supplies the ecosystem services to the populace. Tropical Urban forests contain the greatest diversity in terms of species, genetic material and ecosystem functions like any other forests (Adekunle *et al.*, 2013). Tree species richness serves as major criteria adopted in assessing the importance of an ecosystem for urban forests, landscape conservation and sustainability. In tropical forest, tree species richness plays a vital role in biodiversity because trees directly or indirectly support almost all other life forms (Adekunle *et al.*, 2014; Dar *et al.*, 2019).

The number of tree species reported in the two cities in this study is similar to the values reported for Port Harcourt, Abuja, Lokoja urban forest ecosystems in Nigeria (Agbelade and Onykwelu 2020; Agbelade *et al.*, 2022). Furthermore, the high number of tree species in the urban forests of the two cities studied compared favourably to conventionally managed tropical forests, which has also been reported in other studies in other countries particularly in Nigeria, Ethopia, Niger, Ghana and Benue republic (Teka 2017; Koricho *et al.,* 2020; Moussa *et al.,* 2020; Agbelade *et al.*, 2022). Boadi *et al.*, (2017;), strengthens the belief that urban forests could be repository and reservoir of tree species (Woldegerima *et al.,* 2017).

In urban forests environments management practices are the influencing factor on tree growth characteristics, stand density, volume and biomass of tree (Wu *et al.,* 2015; Agbelade *et al.*, 2016; Agbelade and Onyekwelu 2020). The results on density from past studies indicate that urban tree species of Nigerian cities ranged between 255 and 746 (Agbelade and Onyekwelu 2020; Agbelade *et al.*, 2022). This disagrees with results on density of urban trees in this study which ranged between 892 and 977 for Ikeja and Abeokuta respectively. Individual trees in this study were higher than studies conducted Ibadan, Port Harcourt, Abuja, Minna, Kabba and Omu-Aran.

It has been reported that volume estimation is the determinant of the tree growth structure and the most important

parameter for forest management (Tonolli *et al.,* 2011; Adekunle *et al.,* 2013). The total volume (m^3) of trees for the cities of Ikeja and Abeokuta in this study were 1350.34 and 1971.75 m^3 respectively. This is much higher than the values recorded in similar studies carried out in some urban forests of Port Harcourt (409.8 m^3) and Ilorin (745.4 $m^{3)}$ (Agbelade and Onyekwelu, 2020). Agbelade (2017), Agbelade and Onyekwelu (2020), estimated volume (m^3) of individual trees encountered in the urban and peri-urban areas in three vegetation zones in Nigeria to be: 684.3 and 281.2 m^3 (Ibadan); 907.2 and 321.5 m^3 (Port Harcourt); 752.8 and 191.0 m^3 (Abuja); 428.5 and 291.7 m^3 (Minna); 134.9 and 63.7 m^3 (Kabba) as well as 267.3 and 117.03 m^3 (Omu-Aran).

Urban forest trees diversity and composition

Biodiversity indices are generated to bring the diversity and abundance of species in different habitats to similar scale for comparison and the higher the value, the greater the species richness (IIRS, 2002; Konijnendijk *et al.,* 2004). The higher plant species diversity obtained in the urban and peri-urban residents of Addis Ababa are expected to support the provision of multiple ecosystem services and ensure the survival of plant and animal communities through the provision of essential habitat and food (Woldegerima *et al.,* 2017). The Shannon-Wiener diversity index and species evenness computed for Ikeja were 2.74 and 3.18 and 0.403 and 0.461 for Abeokuta respectively, The Shannon-Wiener diversity for both cities is similar to that estimated for some protected forest. The Shannon–Wiener index recorded for the cities of Calabar and Yenagoa are similar to that recorded for the protected forest of Nigerian and Indian with values of 2.09 and 2.12 (Adekunle *et al.,* 2013). These values are much higher than the diversity index of 0.992 estimated for the mangrove forest in Palawan philippine (Abino *et al.*, 2014). The Shannon-Wiener diversity index of 3.61 recorded for the urban forest of Adama in central Ethiopia was slightly higher than the figure obtained in this study (Koricho *et al.,* 2020).

Species evenness obtained in this study for the cities of Ikeja and Abeokuta were slightly lower than that recorded for the protected forest of Indian and Nigerian forest which were 0.635 and 0.593 respectively Adekunle *et al.,* (2014), while species evenness 0.84 recorded for the urban cities of Ibadan is lower than that obtained for Ikeja and Abeokuta (Agbelade *et al.,* 2016). This finding is in line with Konijnendijk *et al.,* (2004); Agbelade and Onyekwelu (2020), which revealed that the levels of biodiversity in urban areas, are often high when compared with the diversity of natural forest trees.

Volume of biomass and carbon storage

The total estimated biomass for trees in Ikeja was calculated as 1375.41 tons while Abeokuta was 1939.10 tons. This estimated biomass is higher when compared to that of Siberut Island Nature Reserve, West Sumatra (131.92 ton/ha) Bismark *et al.*, (2016) and the Bahile mangrove forest 757.7ton ha^{-1} (Abino *et al.,* 2014; Wu *et al.*, 2015). Carbon storage varies between the two

cities with Ikeja having a total carbon stock of 825.25 tons and Abeokuta 1163.46 tons. The carbon stock estimated for this research is similar to the study conducted in two urban cities in Nigeria. The total carbon stored estimated in a study for the urban forest of Port Harcourt and Ilorin was much higher than the two cities (Ikeja and Abeokuta) studied with values of t 67,979.08 tons and 91,512.49 tons respectively (Agbelade and Onyekwelu, 2020). On the other hand, the average carbon density of 172 tons/ha recorded for the urban forest of Addis Ababa and the 33.22 tons/ha recorded for the urban forest of Shenyang, China (Liu and Li, 2012), are less than the amount of carbon stored for both cities of Ikeja and Abeokuta metropolitan cities. The difference in carbon storage is due to anthropogenic activities and tree species diversity (Norwak and Crane, 2002). Carbon storage and sequestration in a region is a function of the amount of urban land and percentage of tree cover (total amount of urban tree cover). Tree species have different carbon storage capacities and as such smaller trees have lower carbon storage than larger trees. The carbon content of trees in urban areas in this study is an indication that the conservation of biodiversity in urban areas could contribute significantly to greenhouse gas emission reduction (Agbelade and Onyekwelu, 2020). Afforestation with appropriate species with higher canopy for maintaining urban trees can make urban forest a sink for atmospheric carbon, along with the provision other urban forest benefits such as temperature reduction and air pollution mitigation (Cavan *et al.*, 2014).

Conclusion

This study shows that the species diversity and abundance in Ikeja and Abeokuta compared favorably with other urban forest ecosystems. This research has provided baseline information that will be useful to develop urban forest conservation strategies and on which. future assessments and monitoring can be done. This in turn may be used as a tool to protect urban forest trees from degradation. In order to maintain the existing urban tree diversity, sustainable conservation and management efforts should be in place and frequent inventory and survey of trees are also recommended. People should be educated and encouraged on the importance of tree planting and conservation of existing tree species in their environment in order to sustain ecosystem services. Urban tree species seedling should be made available for individual or group of individuals that are interested in having trees around their houses for planting. However, there is still the need for the creation of more awareness on the significance of urban trees.

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INVESTIGATION INTO THE APPROPRIATE MULTIPURPOSE PUSH TYPE TILLAGE MACHINERY FOR MAIZE PRODUCTION ON SANDY LOAM SOIL IN NIGERIA

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Abstract

A combination of tillage machines that integrated the operations of tillage, planting, fertilizer and herbicide applications in one passage of a wheel tractor (IAR Prototype II) was investigated with other split farm operations using maize as a test crop on sandy loam soil. Human energy expenditure, soil penetration resistance, depth of seed placement, seed to distance, and their effects on seed germination and seedling emergence were studied. The data collected were analysed using the analysis of variance (ANOVA) in split –split- plot design and the significant factors were further analysed using Duncan Multiple Range Test (DMRT). Results showed that seed planting depths of 5.3 ± 0.10 cm and 6.1 ± 0.12cm were obtained for prototype 1 and manual planting method, respectively at a moisture content of 24.3 ± 1.03 % w/w. The penetration resistances of prototype 1 (2.2 ± 0.02 MPa), prototype II (1.3 ± 0.01 MPa), and manual planting (2.5 ± 0.06 MPa) at the soil depth of 0 – 10cm were obtained. Increased body weight, increased heart rate.

Keywords: Tillage, machinery, prototype, maize: sandy loam soil

Introduction

Appropriate seedbed preparation, and application of farm inputs are not only critical operations in crop production but also vital factors in obtaining dependable plant population, increase production, productivity and profitability of farming operations. There are urgent needs to liberate Nigerian farmers from back - breaking drudgery of tilling the land by hand hoe through mechanization for increasing acreage under cultivation, improving the quality of seed bed preparation, and raising the efficiency of farm inputs application. Farmers with medium – sized farm holdings of 2 to 10 hectares have the potential to support an intermediate level of mechanization since they find that traditional animal or manual equipment is often inadequate for their requirements (Khan, 1970). Furthermore, sophisticated farm equipment imported from Europe and North America is uneconomical for small and medium - scale farmers because of the high initial cost, low technical knowledge of the farmers and inadequate servicing and spare parts facilities. The fact is that no amount of financial aid infused into the economy from the government can equal the value of encouraging farmers to do things for themselves.

The objectives of this research were to investigate the performance of a combination tillage systems which integrated tillage, planting, fertilizer, and pesticide applications in a pass of a two –wheel tractor (IAR Prototype II) with existing once-over tillage machinery (IAR Prototype I) and manual method. The parameters studied were energy expenditure, seed metering accuracy, seed damage percentage, ease of operation, and seed germination and seedling emergence using maize as a test seed.

Methodology

The study area

On –farm trials were conducted on a rectangular plot of 50m x 40 m on sandy loamy soil at Samaru (Latitude 11° 11' N, longitude 07°38'; Altitude 686m above sea level). The procedure followed in obtaining the soil parameters is as described by Black (1965). The mean annual rainfall 1923 – 1993) for Samaru varies between 608 mm and 1482 mm (Badakin, 1993). The topography is predominantly very gentle adulating plain with the average slope of the field being 0.06%. The experimental field size was 100 x 50m^2

Materials

The materials used consist of prototypes 1 and II**,** rotary injection planter, rotary tiller, landmaster lion single-axle tractor, stethoscope, Griffin bicycle ergometer, and monogram for estimation of maximum O_2 uptake and workload. In addition, a stopwatch, controlled droplet applicator (CDA), measuring tape, knapsack sprayer, fertilizer (NPK 15-15-15), cone penetrometer, and maize seed were used in the research.

Institute for Agricultural Research (IAR) Prototype 1

Onwuji (1983) designed and constructed a once-over tillage machine and its feature consists of two double mouldboard ridger, a rotary punch planter, a fertiliser distributor and a herbicide applicator.

Institute for Agricultural Research (IAR) Prototype II

The appropriate technology combination tillage systems is a combined unit of a rotary tiller, a rotary injection planter, a Fertilizer- Applicator-Band (FAB), and a controlled droplet application (CDA), herbicide applicator (Micro herbi) (Figs. 1 and 2 and Table 1) all mounted on the frame work of a Landmaster Lion single –axle walking tractor powered by a 7 hp Briggs and Stratton petrol engine (Fig. 3). The single-axle tractor has the advantages of light weight and good maneuverability, suits the economic condition and management skills of most Nigerian farmers. Manual power from the operator was used generally as supplementary power to control the machine through the handles of the tractor. Opinions of the operators were sought after the tillage as regards the ease of operation of prototypes 1 and II and the manual method of planting.

Rotary Injection Planter

The rotary injection planter injects the seeds into the soil by a jabbing action and gently compacts the soil using a press wheel attached to the device. This equipment was originally designed by volunteers in the Technical Assistance,

U. S. A. programme and adopted in the region. It is gaining popularity among farmers because of its precise seed metering and ease of operation.

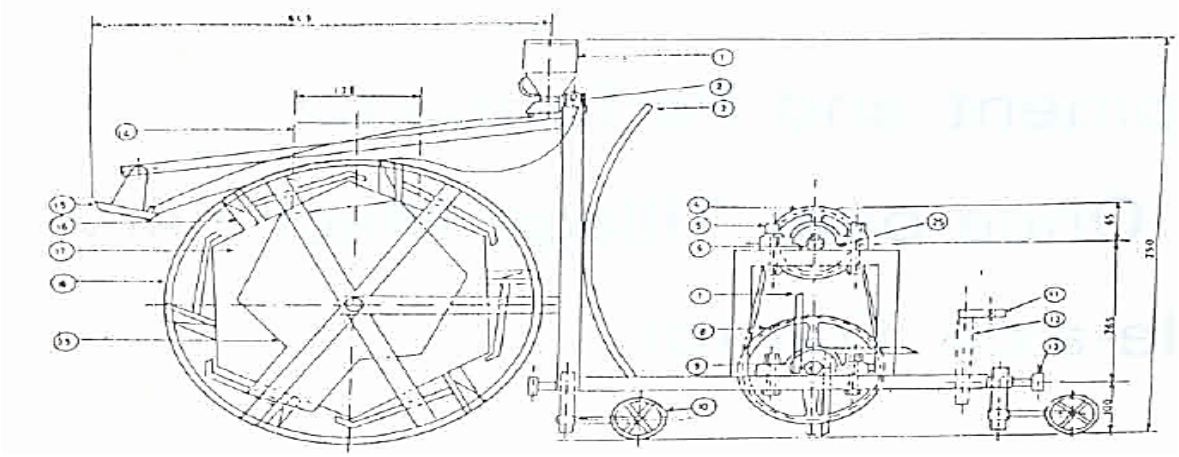

Fig. 1: Side elevation of the combination tillage systems

Rotary Tiller

The Rotary Tiller consists of a rotating drum that is equipped with bent blades for breaking up and leveling soil. The blades are turned through the soil while the machine moves over the working area. A Drag Shield is used to maintain a level seedbed. Rotational power to the drum is provided by the PTO on the tractor. The power is transmitted through the gearbox in the center of the machine to the chain drive down the side. The rotary tiller pulverizes the soil before planting (to aerate the soil and prepare a smooth, loose seedbed). The Tiller was equipped with a Category 1, 3 - point hitch. The tractor 3 - point hitch was in the Category 1 configuration. The operator set the tractor "s hydraulic system.

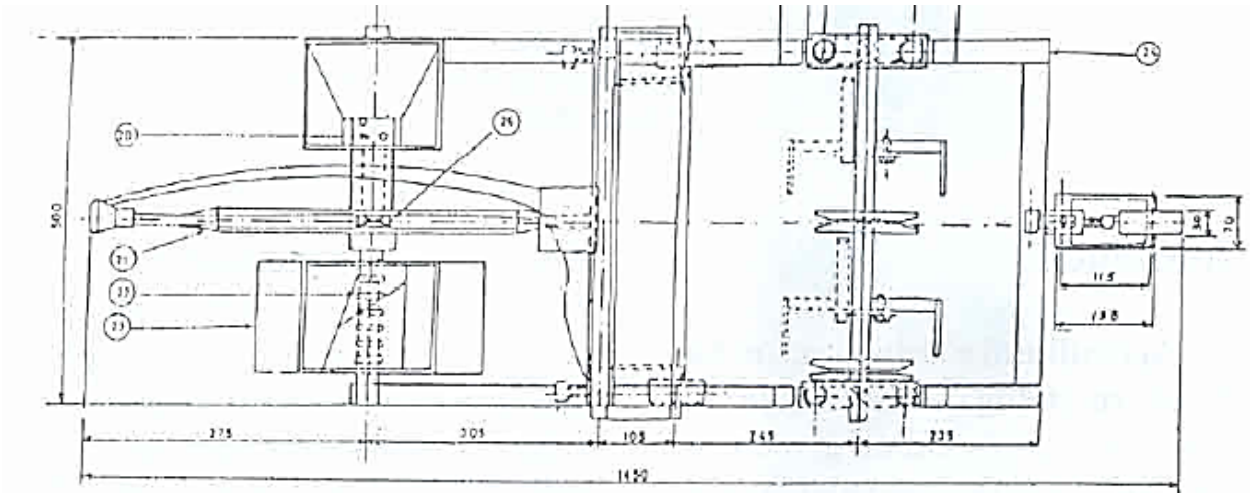

Fig. 2: Top elevation of the combination tillage systems

Fig. 3: Operation of the combination tillage systems in the experimental field

Table 1: Components of the combination tillage systems

26	BALL BEARING	3	CROMAIUM STEEL
25	BEARING CASING	3	MILD STEEL
24	MACHINE FRAME	1	ANGLE IRON
23	FERTILIZER DISTRIBUTOR HOPPER	1	16 GAGE SHEET METAL
22	FERTILIZER AGITATOR	1	ROUND SOLID IRON ROD
21	PUNCHING WHEEL	1	16 GAGE SHEET METAL
20	SEED PLATE	1	HARD WOOD
19	FERTILIZER DISTRIBUTOR UNIT	1	HARD WOOD
18	SUPPORTING WHEEL	1	16 GAGE SHEET METAL
17	ROTARY PUNCH PLANTER	1	16 GAGE SHEET METAL
16	SEED FUNNEL	6	MILD STEEL SHEET
15	CDA SPINING DISC	1	PLASTIC
14	SEED HOPPER	1	16 GAGE SHEET METAL
13	DEPTH CONTROLLER	1	ROUND SOLID IRON ROD
12	MACHINE HITCHSUPPORT	1	ANGLE IRON
11	MACHINE HTCH POINT	1	MILD STEEL SHEET
10	LAND WHEEL	3	MILD STEEL SHEET
9	M8 FLAT WASHER	8	MILD SHEET
8	DRIVEN PULLEY	1	CAST IRON
7	ROTARY TILLER KNIFE	8	MILD STEELSHEET
6	POWER TRANSMISSION SHAFT	2	MEDIUM CARBON STEEL
5	M8 x18 BLACK HORIZONTAL BOLT	8	MILD STEEL
4	DRVER PULLEY	1	CAST IRON
3	PROTECTIVE SHIELD	1	14 GAGE SHEET MATAL
2	BATTERY CASING	1	PASTIC
1	CDA SPRAYER TANK	1	TRANSPARENT PLASTIC
ITEM NO.	**DESCRIPTION**	**NO OFF**	**MATERIAL**

to provide "float" on the 3-point hitch to allow the machine to follow the ground contours during operation. Operating speeds were not more than 540 rpm in order not to overload the drivetrain. The rotary tiller blades are used to achieve the advantages of lower draft requirements better soil breakup and more efficient inversion and trash mixing.

Landmaster Lion Single-axle Tractor

The Landmaster Lion single-axle tractor is a tractor with one axle, self-powered and self-propelled, that pulled and powered a rotary tiller which was integral to the machine and the operator walked behind it with his power for control. The power takeoff (PTO) is a rotating shaft, at the back of the tractor, from which power was taken from the tractor's engine was hooked to up a special spinning rod (with clever, flexible connections called universal joints) between the tractor and the rotary tiller so that the tractor's engine powers the rotary tiller. The tractor was fitted with a 7hp Briggs and Stratton petrol engine which was calibrated to relate the ground speeds to engine speeds and positions of the throttle lever for operator's convenience. Throttle lever positions which corresponds to tachometer speed readings of 800, 1,200, 2,400, 3,000, 3,400 and 3,500 rpm were marked. The tractor travel speed (m/s) was determined by meaning the time taken to travel a distance of 100m on level ground with four replicate observations for each measurement.

Traditional (Manual) Method of Planting

The traditional (manual) planting method represents planting without any form of mechanical aid. It involves dropping seeds into holes made with heels, covering the seeds with heels, and gently compacting the moist soil surrounding the seeds with the heels.

Human Energy Expenditure Estimation

Energy expended in operating each machine was evaluated using heart rate as a physiological index as described by Li et al., (1993). Initially, 48 individuals volunteered to participate in the study. The final sample size was 46 because 2 subjects could not complete the exercise. Each subject carried out each operation over a distance of one hundred (100) meters and their heart beats/min, was measured using a stethoscope. The subjects' energy consumption was later calibrated with the aid of a Griffin bicycle ergometer having a 1.0meter wheel diameter. A monogram for estimation of maximum O_2 uptake and workload (Astrand and Rodhal, 1970) taking body weight and pulse rate as known variables were used. The pulse rate and time required to cover a given area were recorded for each farmer. Time was recorded with a stopwatch. Oxygen intake and workload were recorded during the operation. The physical efficiency index (PEI) of the operators was calculated by using the equation described by Johnson et al., (1942) as:

PEI = Duration at operation in seconds / 2 × sum of pulse counts in recovery ×100 (1)

Each farmer's body surface area (BSA) was calculated using the equations stated by DuBois and DuBois (1916) and Wang et al., (1992) as:

$$BSA\ (m^2) = (W^{0.425} \times H^{0.725}) \times 0.007184 \quad (2)$$

The weight (W) is in kilograms and the height (H) is in centimeters.

Seed Metering Accuracy and Seed Damage Tests

Field tests were carried out to establish the machine's seed metering accuracy and determine the average number of seeds dropped. Spacing between hills was measured. Institute for Agricultural Research (IAR) Prototype II was used in the tests for comparison. A laboratory test was carried out on a flat piece of wood that was coasted with grease to determine the performance of the machine's metering device. For the seed damage test, the machine was operated in the laboratory through a distance of 50 m. The percentage of cracked seeds, broken seeds and lost lip caps of the seeds were computed. The seed row spacing, hill spacing, and depth of seed placement in the field were 75 cm, 25 cm, and 3 cm, respectively. Immediately after planting pre-emergence herbicide (Primagram 500 fw) was sprayed using a knapsack sprayer at the rate of 4 l/ha. However, the plots that received the I.A.R. prototypes 1 and II were treated by using the controlled droplet applicator (CDA) which produced single droplet at about 1 ml per second flow rate with droplets of 250 to 300micron volume media diameter (vmd). Fertilizer (NPK 15-15-15) was applied at the rate of 400kg/ha two weeks after planting in a ring of 10 cm radius and 2.5 cm deep around each stand according to local recommendations.

Soil Characteristics and Penetrometer Measurements

Soil resistance to cone penetrometer pressure was measured before and after planting to determine the soil compaction with a recording penetrometer (Anderson et al., 1980) of 12.8mm diameter and 30^0 angle of conical probe, 1.9cm in diameter and mounted on a 0.95 cm diameter shaft. Measurements were done randomly at 5cm intervals at 30 sampling locations. The soil sample was taken with cylindrical core samplers (size 30cm long x 15cm diameter). The core was inserted into the soil to a depth of 30cm then the soil was removed from its side and a thin disc was slipped under the core. The procedures followed in determining the soil characteristics are as described by Black (1965). Soil dry bulk density and soil moisture content were obtained by using the procedures described by Day (1965) and Blake and Hartge (1986).

Seed Germination and Seedling Emergence Parameters

Germination of maize (Zea mays L.) seeds and the emergence of seedlings were monitored three times every day (morning, afternoon and evening) after planting and final emergence (FE) was recorded when no newly emerged seedlings were observed. Mean emergence time (MET) was calculated using the formula (Ellis and Roberts, 1981):

$$MET = \sum D_n / \sum_n \quad (3)$$

D is the number of days counted from the beginning of emergence and *n* is the number of seeds that had emerged on day D.

Time to 50% emergence (T_{50}) was calculated with the formula of Coolbear et al., (1984), modified by Farooq et al., (2005):

$$T_{50} = t_i + (N/2 - ni)(t_j - t_i)/(n_j - n_i) \quad (4)$$

N is the final number of emerged seeds, n_j and n_i are the cumulative number of seeds that emerged by adjacent counts at times t_j and t_i, respectively, when $n_i < N/2 < n_j$.

Mean emergence data (MED) and emergence rate index (ERI) were calculated using the equation of Bilbro and Wanjura (1982) from the emergence counts as follows:

$$MED = \left(N_1t_1 + N_2t_2 + \ldots\ldots + N_nt_n\right)/\left(t_1 + t_2 + \ldots\ldots + t_n\right) \quad (5)$$

$$ERI = (N_1 + N_2 + \text{---} + Nn) / MED \quad (6)$$

N_1, N_2, --- Nn are numbers of newly emerged seedlings at time t_1, t_2 --- tn

From the emergency counts, the following emergence parameters were also determined using the formular reported by Joshi (1987) as:

Percentage seed and seedling mortality were obtained from the equation (Joshi, 1987) as:

Percentage seed and seedling mortality =

$$\frac{100 - UE}{\text{Lab. germination \%}} \quad (7)$$

UE = Ultimate emergence (the maximum number of seedlings that emerged during the experiment).

Mean period of ultimate emergence (MPUE) =

$$\sum_i^n \frac{N_i D_i}{UE} \quad (8)$$

Emergence Rate (ER) =

$$\sum_i^n \frac{N_i}{D_i} \quad (9)$$

N = daily increase in seedling number

D = number of days from sowing

UE = ultimate emergence (the maximum number of seedlings that emerged during the experiment)

The recovery efficiency (RE) of added nitrogen (N) was calculated from equation (Dilz, 1988) as:

$$RE = \frac{\text{Total N uptake (kgha}^{-1}\text{) treatment} - \text{Total N uptake (kgha}^{-1}\text{) control}}{\text{Applied N (kg N ha}^{-1}\text{) treatment}} \quad (10)$$

Agronomic efficiency (AE) of added N was calculated (Novoa and Loomis, 1981) as:

AE (Kg grain Kg N applied) =

$$\frac{\text{Grain yield (Kg Nha}^{-1}\text{) treatment - grain yield (Kg Nha}^{-1}\text{) control}}{\text{Applied N (Kg Nha}^{-1}\text{) treatment}} \times 100 \quad (11)$$

Analysis of Experimental Data

The data collected was statistically analysed with statistical analysis software (SAS, 1989)) package and the analysis of variance (ANOVA) in a three - factor experiment using the procedure of split

– split – plot design as described by Gomez and Gomez (1983). The significant factors were further analysed using Duncan Multiple Range Test (DMRT).

Results and Discussion

Atmospheric pressure, air temperature and relative humidity at the site during the test period are shown in Table 1. The atmospheric pressure increased from 750 .0 to 752.0 mmHg on the first test day and 760.5 to 765.0 mmHg. the seventh day. Air temperature varied from 30.4 to 37.3°C and relative humidity from 61.0 to 82.0% on the first day of the field test. The soil physical properties of the study area are shown in Table 2. Soil clay contents increased with an increase in soil depth. Due to the high clay content of the soil, workability is a constraint in the area when wet, the soil is plastic but hard upon drying and the manual soil tillage becomes difficult. This partly explains why the tillage device is receiving acceptance by farmers in the area as a substitute for human power usage. The course –textured top soil (0 - 20cm) was freely draining and cultivation was relatively easy. The total nitrogen content of the soil varied from 0.04% w/w to 0.06 % w/w while the soil pH increased from 5.4 to 6.1within the soil depth of 0 – 30cm. Available water capacity (AWC) ranged from 8.3% to 10.1%. The amount of water that the soil can store that is available for use by plants being the water held between field capacity and the wilting point was affected by soil texture. The top soil (sandy loam) of 0 to 10cm had AWC of 8.3% with sand, silt and clay proportions of 67%, 22% and 11%, respectively while the 20cm to 30cm soil depth (clay loam) showed AWC of 10.1% with sand, silt and clay proportions of 63%, 15% and 22%, respectively.

Table 1: Weather data during the test days

Test Days	Atmospheric Pressure (mmHg)	Air Temperature (°C)	Relative Humidity (%)
1	750.0 – 752.0	30.4 -37.3	61.0 – 82.0
2	754.5 – 755.0	27.8- 33.0	67.5 – 83.5
3	755.5 - 757.0	25.0 – 31.5	69.0 - 87.0
4	757.5 - 760.0	23.6 – 29.0	70.0 – 90.0
5	758.0 – 760.5	22.1 – 28.2	71.5 - 92.0
6	760.0 - 762.5	21.0 – 30.8	68.5 - 95.5
7	760.5 - 765.0	20.7 - 31.0	70.0 - 95.0

Table 2: Physical and chemical characteristics of the experimental site soil before the initiation of tillage treatments

Soil Depth [a] (cm)	Sand (%, w/w)	Silt (%, w/w)	Clay (%, w/w)	pH	Total N (%, w/w)	Org.C (%, w/w)	Avail.P (ppm)	Exchangeable cations Ca^{2+} (m.eq./100 g soil)	Mg^{2+} (m.eq./100 g soil)	K^{+} (m.eq./100 g soil)	Na^{+} (m.eq./100 g soil)	A.W,C.[b] (%)	Effective C.E.C (meq./100 g soil)	B.S.[c] (%)
0- 10	67	22	11	5.4	0.04	0.6	8.4	2.7	1.2	0.4	0.2		8.3	8.4
53. 6														
10-20	69	19	12	5.8	0.07	0.3	3.7	2.5	0.8	0.3	0.2		9.3	7.3
52.10														
20-30	63	15	22	6.1	0.06	0.5	4.2	2.4	0.6	0.2	0.1		10.1	6.2
53. 2														

[a] Each value is a mean of 10 random single measurements
[b] A.W.C = Available water capacity (field capacity – Permanent witting point)
[c] B.S (%) = Base saturation = (Ca^{2+} + Mg^{2+} + K^{+} + Na^{+} / Effective C.E.C) x 100

Table 3 shows the distribution of personal data of the 46 subjects used for the field operation. The subjects' body weight of 55kg to 60kg was 54.3% in percentage and body surface area of 1.3 m^2 to 1.6 m^2 was 58.7% in percentage. The major occupation of the subjects is farming with 50% of them having farming experience of 5 to 10 years but 45.7% of the subjects had primary education with married status of 91.3%.

Table 3: Distribution of personal data of subjects used for the field operation (n = 46)

Subjects' data	Frequency	Percentage
Gender:		
Male	33	71.7
Female	13	28.3
Age (years):		
30 – 40	27	58.7
41 – 50	13	28.2
51 – 60	5	10.9
> 60	1	2.2
Height (m):		
1.1 – 1.4	11	23.9
1.5 – 1.8	27	58.7
1.9 - 2.2	8	17.4
Body weight (kg):		
55 – 60	25	54.3
61 – 66	17	37.0
67 – 72	4	8.7

Body surface area (m^2):		
1.3 - 1.6	27	58.7
1.7 - 2.0	19	41.3
Physical efficiency index (PEI):		
54 – 59	6	13.0
60 – 65	19	41.3
55 – 71	21	45.7
Marital status:		
Married	42	91.3
Single	4	8.7
Major occupation:		
Farming	46	100
Non- farming	0	0
Farming experience (years):		
< 5	19	41.3
5 - 10	23	50.0
11 - 20	3	6.5
21 – 30	1	2.2
Education:		
No formal education	14	30.4
Primary education	21	45.7
Secondary education	9	19.6
Tertiary education	2	4.3

Effects of travel speed and machine type on mechanically damaged seeds are shown in Table 4. The higher the speed of forward travel, the lower the number of seeds dropped and the higher the percentage of mechanically damaged seeds. Results from laboratory tests showed a lower seed damage percentage than field tests. Lower seed damage percentages were obtained in prototype II than in prototype 1. Prototype II could be more satisfactorily used to plant maize seeds than prototype 1. This was because of the improvements made on the furrow opener and seed metering and placement devices. The brush fitted into the seed hopper of prototype II and adequate clearance between the hopper and seed plate prevented the seed breakage. Hence, seed picking efficiency was increased while the seed damage was reduced in prototype II.

Table 4: Effects of travel speed and machine type on mechanically damaged seeds

Mechanically damaged seeds (%) *					
Travel speed (m/s)	Seed dropped(no)	I. A. R. Prototype 1		I. A. R. Prototype II	
		Field	Laboratory	Field	Laboratory
1.2	336	1.40 ± 0.01	1.20 ± 0.03	1.10 ± 0.06	1.00 ± 0.03
2.5	300	1.70 ± 0.08	1.40 ± .04	1.22 ± 0.06	1.12 ± 0.01
3.2	274	2.10 ± 0.03	1.70 ± 0.05	1.34 ± 0.02	1.20 ± 0.03
4.1	143	2.60 ± 0.01	1.90 ± 0.06	1.52 ± 0.04	1.31 ± 0.04

* Each value is a mean of ten single measurements ± standard deviation

Hill spacing of 0.41± 0.01m for prototype 1 and 0.25±0.01m for prototype II were obtained during field operation (Table 5). Seed dropped per hill of 1.30±0.02 and 1.00±0.01were obtained during field operation for prototypes 1 and II, respectively. Prototype II showed better results as compared to the recommended hill spacing and seed per hill on the flat of 25cm and 1.00, respectively by Kim *et al*, 1984. Prototype II was able to plant maize seeds accurately within the recommended seed spacing. This has hitherto been challenging to achieve with most available once –over tillage machines in Nigerian markets. A similar superior result was obtained for prototype II in the percentage total seeds planted of 57.30±1.23, 93.00±2.03 and 34.00±1.31 for prototype 1, prototype II and manual, respectively for planting 1 seed per hill during field operation. The lowest percentage of total seeds planted of 4.00±0.02 and 1.00±0.01for planting 2 seeds per hill and 3 seeds per hill, respectively were obtained for prototype II.

Table 5: Spacing and planting rates of I.A.R. prototypes 1 and II and manual Values for machines and manual

Parameter Recommended		I. A. R. Prototype 1		I. A. R. Prototype II	Manual	Value*
Hill spacing (m)	0.25	Field 0.41± 0.01	Laboratory 0..32± 0.02	Field 0.25±0.01	Laboratory 0.27± 0.03	Field 0.98±0.01
Seed / hill	1.00	1.30±0.02	1.25± 0.03	1.00±0.02	1.05±0.03	1.50±0.04
Seed planting rate (percentage of the total seeds planted)						
Missed the hill (%)	-	37.00±1.03	13.00±0.7	7.00±0.05	2.00±0.02	36.00±1.12
1 seed/ hill	-	34.00±1.15	57.30±1.23	88.00±1.52	93.00±2.03	34.00±1.31
2 seeds/ hill	-	20.00±1.09	24.00±1.04	4.00±0.02	3.00±0.01	17.00±1.00
3 seeds/ hill	-	6,00±1.00	5.00±0.04	1.00±0.01	2.00±0.03	11.00±0.07
4 seeds/ hill	-	3.00±0.07	1.00±0.01	-	-	2.00±0.02

* *Kim et al.,* (1984)

Note: Each value is a mean of ten random single measurements ± standard deviation

Depth of seed placement of 4.0 + 0.11cm_was obtained for_prototype II (Table 6) which is within the recommended planting depth of 3-5cm (Kim et al., 1984). More pressure exerted has caused seed placement to be somewhat deeper than normal and shallower planted seed emerged more quickly in the wetter soil conditions. Seed planting depths of 5.3 ± 0.10 cm and 6.1 ± 0.12cm were obtained for prototype 1 and the manual planting method, respectively at moisture content of 24.3 ± 1.03 % w/w. Performance evaluation showed important improvement in prototype II with more accurate seed spacing and seed dropped per hill. Soil water content was found to be an important factor affecting the penetration resistance. Soil penetration resistance increased with increased soil depth and soil clay but decreased with increased soil moisture content. This result is in agreement with Lin and Schulze, (2014) who reported that soil resistance to penetration, generally increases with increasing clay, but decreases with increasing soil moisture. Brady and Weil (2008) also reported that non-cohesive soils such as sands and sandy loams are more easily penetrated than clay soils and wet soils have low penetration resistances. Uncultivated soil showed the highest penetration resistance (2.8 ± 0.09 MPa) as compared to the penetration resistances of prototype 1 (2.2 ± 0.02 MPa), prototype 11(1.3 ± 0.01 MPa) and manual planting (2.5 ± 0.06 MPa) at the soil depth of 0 – 10cm.

Table 6: Soil depth of seed placement and penetration resistance at three different moisture contents levels

		Depth of seed placement (cm)				Soil penetration resistance (MPa)			
Soil depth (cm)	Soil moisture content (% w/w)	Recommended values*	I. A. R. Prototype 1	I. A. R. Prototype II	Manual	Untilled Field	I. A. R. Prototype1	I. A. R. prototype II	Manual
0-10	24.3±1.03	3 - 5	5.3 ± 0.10	4.0 ± 0.11	6.1 ± 0.12	2.8 ± 0.09	2.2 ± 0.02	1.3 ± 0.01	2.5 ± 0.06
10-20	21.1±1.21	-	-	-	-`	3.2`± 0.07	2.4 ± 0.01	1.8 ± 0.02	2.8 ± 0.05
20-30	18.5±0.21	-	-	-	-	3.7 ± 0.03	2.6 ± 0.04	1.9 ± 0.01	3.1 ± 0.07

** Kim et al.,* (1984)

Note: Each value is a mean of ten random single measurements ± standard deviation, after two rains (>50mm) at planting

Soil tillage methods significantly (at $p \leq 0.05$) affected the mean penetration resistance, depth of seed placement and recovery efficiency of added nitrogen (Table 7). Prototype II showed the lowest depth of seed placement (3.01cm) and the highest recovery efficiency (73.51%) of added nitrogen as affected by tillage methods. Similarly, soil tillage methods significantly (at $p \leq 0.05$) affected the seed germination and seedling emergence parameters of mean emergence time, time to 50% emergence, emergence rate, emergence rate index, final emergence, and seed and seedling mortality and their

interactions (Tables 8 and 9). Prototype II had the highest final emergence of 90.34% and lowest seed and seedling mortality of 9.66% while manual method of planting had the lowest final emergence of 77.93% and highest seed and seedling mortality of 22.07%. The lowest percentage of seedling emergence recorded for the manual method was due to high penetration resistance which increased mean emergence time (7.50 days), and time to 50% emergence (5.21 days), but reduced emergence rate (29.43% day^{-1}), and emergence rate index (4.32 seed day^{-1}). However, there was no significant difference (at $p \leq 0.05$) in the emergence rate between prototypes 1 and II. It implies that the two machines are effective in influencing the emergence rate of maize seed. This is in agreement with Chen and Weil (2011), who reported that increased soil compaction negatively affected the growth of crops by way of reduced root development, decreased soil infiltration of water and tree root growth. The manual method of planting showed a penetration resistance of 2.03MPa. A penetrometer measurement of 2 MPa is of general concern as it is sufficient to impede the growth and development of plants (Taylor and Gardner, 1963).

Table 7: Results of mean penetration resistance (PR), depth of seed placement (DSP), and recovery efficiency (RE) of added nitrogen (N) as affected by tillage methods

Tillage method	PR (MPa)		DSP	RE
	Untilled soil	Tilled soil	(cm)	(%)
Prototype 1 (P1)	2.24a	1.84ab	4.81ab	61.78b
Prototype II (P II)	2.21a	1.34b	3.01b	73.51a
Manual (M)	2.22a	2.03a	5.13a	51.24c

Means in a column for each variable followed by different letters are indicating a significant difference at $p \leq 0.05$ using DMRT

Table 8: Results of mean emergence time (MET), time to 50% emergence (T_{50}), emergence rate (ER), emergence rate index (ERI), final emergence (FE), and seed and seedling mortality (SSM) as affected by tillage methods.

Tillage method	MET (days)	T_{50} (days)	ER (% day^{-1})	ERI (seed day^{-1})	FE (%)	SSM (%)
Prototype 1 (P1)	7.01a	4.13b	39.34a	5.02 b	84.80b	15.20b
Prototype II (P II)	6.22b	3.11 bc	40.72a	7.11a	90.34a	9.66 c
Manual (M)	7.45a	5.21a	29.43b	4.32c	77.93b	22.07a

Means in a column for each variable followed by difference letters are indicating a significant difference at $p \leq 0.05$ using DMRT

Table 9: Analysis of variance (split-split-plot design) of seed germination and seedling emergence parameters as affected by tillage treatment.

Source of Variation	DF	SS	MS	F-Value [a]	Pr>F
Replication	3	403.259	134.420	1.76^{ns}	0.1599
Main plot factor (A)	5	2012608.426	402521.685	5258.54*	<0.0001
Error (a)	15	942.019	62.801	0.82^{ns}	0.6531
Sub-plot factor (B)	2	23741.370	11870.685	155.08*	<0.0001
A X B	19	403607.907	403 60.791	527.27 *	<0.0001
Error (b)	36	2554.722	70.965	0.93 ^{ns}	0.5909
Sub-sub plot factor (C)	2	10770.898	5385.449	70.36 *	<0.0001
A X C	4	905.602	226.400	2.96*	0.0231
B X C	10	10097.880	1009.788	13.19*	<0.0001
A X B X C	20	45052.620	2252.631	29.43*	<0.0001
Error (C)	108	1668868.300	15452.500		
Total	215	227352045.000			

[a] * = Statistically significant at $p \leq 0.05$; ns = not statistically significant at $p \leq 0.05$

During the tillage operation, there was a close relationship between heart rate and energy expenditure (Fig. 1). Increased body weight, increased heart rate in using the three tillage methods investigated. Similarly, an increased workload, resulted in an increased heart rate. Thus, the longer the time of operation, the more intense the physical activity, and the greater the energy expenditure. These results are in agreement with Rennie *et al.*, (2001) that developed a prediction model using a sample of 789 individuals, and Hiilloskorpi et al., (1999) that developed a prediction equation for energy expenditure from heart rate, using multiple regression analysis, on a sample of 87 healthy, active men and women. They both had significant effects on the relationship between heart rate and energy expenditure including body weight of the subjects.

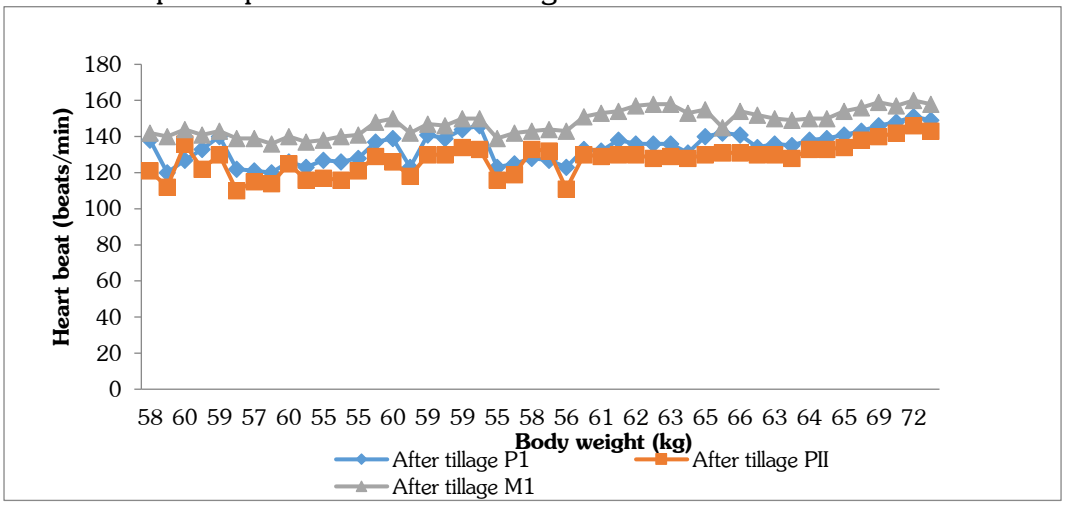

Fig. 1: The relationship between the heart rate and body weight in tillage operation.

Conclusions

Based on the results, knowledge of the linear relationships between penetration resistance, and soil moisture, for cultivated and uncultivated soils can assist in understanding root growth responses to soil tillage and soil compaction. The percentage total seeds planted of 57.30±1.23, 93.00±2.03 and 34.00±1.31 were obtained for prototype 1, prototype II and manual, respectively for planting 1 seed per hill during field operation. Prototype II had a comparative advantage over Prototype 1 and the manual method in terms of time input requirement, seed damage, accurate depth of seed placement, recovery efficiency of added nitrogen, soil penetration resistance, improved seed germination and seedling emergence and they were found to be statistically significant at $p \leq 0.05$.

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ASSESSMENT OF TREE SPECIES DIVERSITY STATUS OF IDANRE AND OLUWA FOREST RESERVES, TROPICAL RAINFOREST ZONE OF SOUTH-WESTERN, NIGERIA

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Abstract

This study was conducted in Idanre and Oluwa forest reserves in Ondo State, Nigeria to examine their species diversity status. Each of the forest reserve was classified into undisturbed and disturbed Land Use (LU) classes. The forest reserves were gridded into 115 m x 115 m and overlaid on the forest reserves shapefile. The grids were called as cluster. Two clusters were selected from each LU class and containing three main plots of 35 m x 35 m as elbow, north and east plots arranged in an L-shape in alternate pattern. In addition, each main plot contained three nested plots of 2 m x 2 m, 7 m x 7 m and 25 m x 25 m. These nested plots were used to enumerate trees with diameters: 2 cm – 5.0 cm; 5.1 cm – 20.0 cm; 20.1 cm – 40.0 cm, respectively while the main plots were used to enumerate trees >40.0 cm. The tree data obtained were restricted to scientific or local name and diameter at breast height (Dbh) of trees. The Paleontological Statistics (PAST) and R-studio software were used for data analysis. The diversity indices assessed varied between the LU classes as well as forest reserves. Over 30 % of the tree species encountered in the two forest reserves were classified as threatened. Though, the forest reserves hold great biodiversity potentials if maintained. Therefore, there is need to strengthen their conservation efforts.

Keywords: Biodiversity; indices; land use; cluster; data; forest reserve, conservation

Introduction

The Tropical rainforests are incredibly important due to their high levels of biodiversity (Onyekwelu *et al.*, 2008; Owusu *et al.*, 2022). They house a significant portion of Earth's plant and animal species and they provide essential ecosystem services such as regulating air quality, moderating temperature and managing watersheds (Banerjee and Bandopadhyay, 2016). These forests also offer resources like shelter, food, medicine and income for local communities (Adeyemi *et al.*, 2015).

However, human activities, such as deforestation and forest degradation, pose a severe threat to tropical rainforests (Onyekwelu *et al.*, 2008; Owusu *et al.*, 2022). These activities are often driven by factors like population growth and demand for timber, leading to habitat destruction, loss of biodiversity and erosion of genetic resources (Owusu *et al.*, 2022).

The Nigeria tropical rainforest ecosystem, like many other tropical rainforests, has been heavily impacted by logging and other anthropogenic activities (Adekunle *et al.*, 2013). High demand for timber has led to unregulated exploitation of forests, resulting in severe degradation (Adekunle *et al.*, 2013). This degradation has led to the fragmentation of forests, making it necessary to assess the current status of biodiversity in these ecosystems (Bila and Mabjaia, 2012).

Consequently, it is crucial to study and understand the current state of biodiversity in tropical rainforest ecosystems like the ones in Idanre and Oluwa forest reserves. This knowledge can inform effective conservation and management strategies to protect these ecosystems and their vital biodiversity (Neelo *et al.*, 2015).

This study was conducted specifically in Idanre and Oluwa forest reserves in Ondo State, Nigeria. These reserves were chosen due to their significance as hotspots of deforestation activities, which underscore the urgency of studying and conserving biodiversity in these forest reserves. This will provide useful information for the forest conservation and management of the rainforest ecosystem. These reserves were chosen due to their significance as hotspots of deforestation activities, which underscore the urgency of studying and conserving biodiversity in these forest reserves. This will provide useful information for the forest conservation and management of the rainforest ecosystem.

Materials and Methods

The study area

The study was carried out in Idanre and Oluwa Forest Reserves in Ondo State, Nigeria. The two reserves are among the foremost forest reserves in Nigeria (Oke *et al.*, 2020). The farmers, loggers and hunters who lived on the fringes of these forest reserves constitute devastating effect on the biodiversity potentials of the forest reserves. Idanre Forest Reserve is situated in Idanre Local Government Area of Ondo State, Nigeria. It lies between Latitudes 6.672 °N to 6.960 °N and Longitudes 4.96 °E to 5.280 °E and covers an area of about 561 km². The general terrain of Idanre forest reserve stands at an elevation of between 286 and 500 m above sea level. The mean annual temperature and relative humidity of the forest reserve are 32°C and of 70 %, respectively (Oladeji *et al.*, 2022), while the mean annual rainfall is about 2000 mm (Olugbenga *et al.*, 2011). Idanre forest reserve comprise of rocks with wide variations in grain size and mineral composition including very coarse grain and also from acid quartzite to basic rocks contain amphibolite in large quantity (Olugbenga *et al.*, 2011). Idanre and its environment are overlaid with metamorphic rocks of the basement complex, the great majority being of ancient pre-Cambrian age (Olugbenga *et al.*, 2011). The configuration of the drainage in Idanre forest reserve is normally dendritic in which water flow developed along major point directions and their sequences are generally straight (Olugbenga *et al.*, 2011). The shallow valleys and cracks accommodate some small, big and tall trees such as *Alstonia congensis*, *Baphia nitida* and *Diospyros monbuttensis etc* (Olugbenga *et al.*, 2011). These tree species take opportunity of the deep soil directly from weathering of the base rocks.

Oluwa forest reserve is situated in Odigbo Local Government Area of Ondo State, Nigeria. It lies between Latitude 6.640 – 6.980 °N and Longitude 4.420 – 4.880 °E and covers an area of 829 km^2. Annual rainfall in Oluwa forest reserve ranges between 1700 and 2200 mm (Ogunjemite and Olaniyi, 2012). Annual mean temperature is about 26 °C. The relative humidity is high and uniform, ranging between 75% and 95%. The elevation of the forest reserve lied approximately between 300 and 600 m above sea level (Ogana and Gorgoso-Varela, 2015). The soils of Oluwa forest reserve are predominantly ferruginous tropical, typical of the variety found in intensively weathered areas of basement complex formations in the rainforest zone of south-western, Nigeria (Onyekwelu *et al.*, 2008). The soils are well-drained, mature, red, stony and gravely in upper parts of the sequence (Ogunjemite and Olaniyi, 2012). Onyekwelu *et al.*, (2008) reported that Oluwa forest reserve has a topsoil texture that is mainly sandy loam. The vegetation of the reserve belongs to tropical rainforest with species such as *Melicia excelsa*, *Terminalia superba* and *Triplochiton scleroxylon, etc* (Ogunjemite and Olaniyi, 2012).

Plot layout

Data for this study were collected from two land use (LU) classes within each of the two forest reserves (Idanre and Oluwa). The LU types were undisturbed forest (defined as areas with more than 50 % canopy cover) and disturbed forest (defined as areas with less than 50 % canopy cover). Regular square grids of 115 m x 115 m were created in ArcGIS and overlaid on the shapefile of the study areas, which were called clusters. Stratified random sampling was adopted in selecting sample plots with the LU classes serving as the strata. This sampling design was used in order to capture the variability within the forest reserves. Therefore, two clusters were randomly selected from each LU class using random number to avoid bias. In each selected cluster, three temporary sample plots of 35 m x 35 m representing elbow, north and east plot (parent/main plots) were laid systematically by using the cluster's southwest intercept coordinate to start the elbow plot and then move 10 m distance to the north and east to lay the other two plots outwardly (Fig. 1). Again, each parent plot (35 m x 35 m) contains three nested plots (2 m x 2 m, 7 m x 7 m and 25 m x 25 m) designed to cover different tree diameter classes.

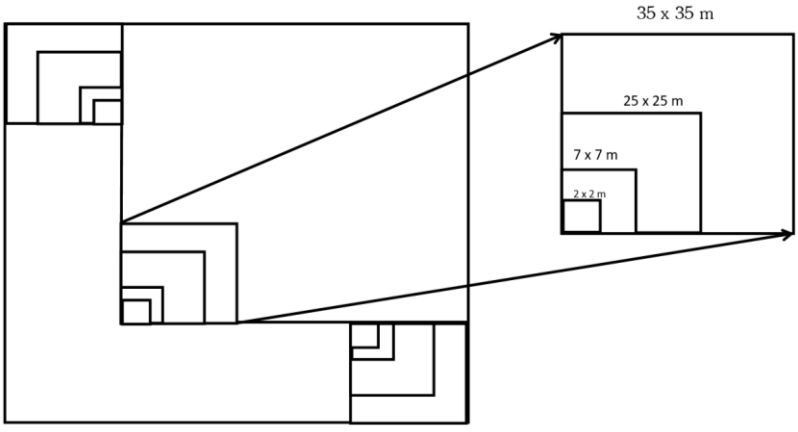

Figure 1: Cluster and sample plot arrangement

Data collection

The trees with Dbh > 40.0 cm were enumerated within the parent plot while trees with Dbh between 20.1 cm and 40.0 cm were enumerated within the 25 m x 25 m nested plots. Trees with Dbh between 5.1 cm and 20.0 cm were measured within the 7 m x 7 m nested plots while trees with Dbh between 2.0 cm and 5.0 cm were enumerated within 2 m x 2 m nested plots. Dbh and identification (by scientific or local names) of all live trees were measured. The identification was carried out by forest taxonomist, who is conversant with trees in tropical rainforest ecosystem of Nigeria. For trees that could not be identify in the field, samples (*e.g.* fruit, leaves and bark *etc.*) were collected and used for their identification in the herbarium at the Federal University of Technology, Akure, Nigeria.

Data Processing and Analyses

Data collected was imported into Paleontological Statistics (PAST) and R-studio software for diversity analysis. Species diversity refers to number of different species present in a community and relative abundance of each species. The measures for species diversity include; species richness, Pielou's species evenness, Shannon-Wiener diversity, relative density, relative dominance and importance value index (Gonçalves *et al.*, 2017). The species diversity indices were computed as follows:

1. Species richness, which refers to the total number of species recorded in a given ecosystem.

2. Shannon-Wiener diversity Index was estimated with equation 1.

$$H = -\sum_{i=1}^{s} p_i \, ln(p_i) \quad \text{Equation 1}$$

Where: H = Shannon-Wiener diversity iindex; p_i = number of individuals of species in a given forest (plot) divided by the total number of individuals in the plot; s = total number of species in the community; ln = the natural logarithm; Σ is summation

3. Pielou's Species evenness was computed using Equation 2 as adopted by Sholiqin *et al.* (2021)

$$En = \frac{ln(H)}{S} \quad \text{Equation 2}$$

Where: En = Evenness Index; H = Shannon-Wiener diversity index, ln = natural logarithm; S = the total number of species in the community

4. Margalef Index (*M*): Margalef index, which is a measure of the number of different species represented in the forest community (species richness), was computed as shown in equation 3 (Margalef, 1982).

$$M = \frac{S-1}{lnN} \quad \text{Equation 3}$$

Where: M = Margalef Index, S = total number of species in the community; N = total number of individuals in the site; ln = natural logarithm

5. Relative density (RD) (%) of each species was computed using Equation 4 (Brashears *et al.*, 2004). The status of tree species in each community was defined using the following RD classification: "Abundant" when RD is equal to or greater than 4.00%; "Frequent" when RD ranges between 3.00% and 3.99%; "Occasional" when RD ranges between 2.00% and 2.99%; "Rare" when RD ranges between 1.00% and 1.99%; and

"Threatened/endangered" when RD is less than 1.00% (Ajayi and Arowosoge, 2018).

$$RD = \left(\frac{ni}{N}\right) \times 100 \quad \text{Equation 4}$$

Where: RD = Relative Density of the species; ni = the number of individuals of species i; N = total number of all individual trees.

6. Relative dominance (RDo) (%) of each species was estimated using Equation 5:

$$RDo = \frac{(\Sigma Ba_i \times 100)}{\Sigma Ba_n} \quad \text{Equation 5}$$

Where: RDo is the relative dominance of the species; Ba_i = the basal area of all individual trees belonging to a particular species i; Ba_n = the total basal area estimated for the stand.

7. Importance Value Index (IVI): The sum of the Relative Density and Relative Dominance divided by 2 (i.e. (RD x RD_o)/2) (Equation 6) gave the IVI for each species in this study (Yang *et al.*, 2008; Adekunle *et al.*, 2013).

$$IVI = \frac{RD + RDo}{2} \quad \text{Equation 6}$$

Results

Tree species composition

A total of 36 and 39 tree species were enumerated for disturbed and undisturbed forests, respectively of Idanre forest reserve. Oluwa forest reserve had 32 and 33 tree species in the disturbed and undisturbed areas, respectively. The average stems per hectare were enumerated at 415 and 138 stems ha^{-1} for disturbed and undisturbed areas of Idanre forest reserve, respectively while in Oluwa forest reserve, the average of 556 and 219 stems ha^{-1} were encountered in the disturbed and undisturbed forest, respectively.

An extrapolation of the density of individual trees revealed that in disturbed land use class of Idanre forest reserve had it highest tree species stems per hectare of 2500 stems ha^{-1} as recorded for *Grewia pubescens* P. Beauv., *Diospyros mespiliformis* Hochst. ex A. DC. and *Rauvolfia vomitoria* Afzel. This was followed by *Vernonia amygdalina* Delile and *Diospyros monbuttensis* Gürke with 1926 and 1857 stems^{-1}, respectively. The lowest density (8 stems ha^{-1}) was recorded for tree species like *Cola gigantea* A. Chev and *Chrysophyllum albidum* G. Don, *etc* (Table 1). In Oluwa forest reserve, the disturbed forest land use class had its highest individual tree density (2500 stems ha^{-1}) for *Blighia unijugata* Baker, *Holarrhena floribunda* (G. Don) Dur. & Schinz APD acc, *Napoleona imperialis* P. Beauv. and *Rinorea brachypetala* (Turcz.) Kuntze. This was followed by *Diospyros dendo* Welw. ex Hiern and *Baphia nitida* Load with 1735 stems ha^{-1} each. Tree species with lowest stem ha^{-1} in disturbed area of Oluwa forest reserve was *Sterculia rhinopetala* K. Schum with 12 stems ha^{-1} (Table 2).

The undisturbed forest land use class of Idanre forest reserve had *Anthonotha macrophylla* P. Beauv as the tree with highest tree density (1592 stems ha^{-1}) followed by tree species like *Carpolobia lutea* G. Don, *Diospyros dendo* Welw. ex Hiern and *Cola heterophylla* P. Beauv. Schott & Endl. *etc* with 204 stems ha^{-1}. The lowest density (8 stems ha^{-1}) was recorded for five tree species (Table 3). For the undisturbed forest land use class in Oluwa forest reserve, highest density (588 stems ha^{-1}) was recorded for *Bridelia*

micrantha (Hochst.) Baill. This was followed by *Discoglypremna caloneura* (Pax) Prain with 510 stems ha^{-1}. The lowest density was recorded for *Holoptelea grandis* (Hutch.) Mildbr, with eight stems ha^{-1} (Table 4).

The number of families encountered in this study ranges from 13 to 24 families. The undisturbed land use of Idanre forest reserve had the highest number of 24 families, followed by disturbed land use of Idanre and Oluwa forest reserves with 20 families each. The lowest number of families encountered was recorded for the undisturbed area of Oluwa forest reserve with 13 families. The family of Euphorbiaceae had the highest number of occurrence in the undisturbed portion of Oluwa forest reserve with seven (7) tree species. Five (5) tree species were also recorded for Euphorbiaceae family in disturbed portion of Idanre forest reserve, which was followed by four (4) tree species in disturbed area of Oluwa forest reserve and three (3) tree species in the undisturbed portion of Idanre forest reserve. The family of Sterculiaceae and Ulmaceae had three tree species each in disturbed forest land use class of Idanre forest reserve.

Tree Species Abundance

The abundance status for each of the tree species encountered was captured under the following indices; relative density, relative dominance and important value. About 41.67 % of tree species encountered in disturbed forest of Idanre forest reserve were classified as "threatened". But some few tree species found in the disturbed forest of Idanre forest reserve were classified as "abundant" (16.67 %) which include; *Anthonotha macrophylla* P. Beauv., *Ficus exasperata* Vahl, *Diospyros monbuttensis* Gürke, *etc*. In the same vein, the undisturbed forest of Idanre forest reserve had 48.72 % of its tree species encountered designated as "rare" while 15.38 % of the tree species found were classified as "abundant" which include; *Ricinodendron heudelotii* (Baill.) Heckel, *Anthonotha macrophylla* P. Beauv. *Musanga cecropioides* R.Br, *etc*.

Furthermore, the disturbed and undisturbed forest of Oluwa forest reserve had 34.38 % and 42.42 % of their encountered tree species classified as "rare", respectively. Some of the tree species found in disturbed forest of Oluwa forest reserve were classified as "abundant" (25 %), which include; *Ricinodendron heudelotii* (Baill.) Heckel, *Musanga cecropioides* R.Br, *Picralima nitida* (Stapf) Th. & H. Dur., *etc*. Again, the undisturbed forest of Oluwa forest reserve had some of tree species encountered classified as "abundant" (15.15 %) which include; *Ricinodendron heudelotii* (Baill.) Heckel, *Anthonotha macrophylla* P. Beauv., *Picralima nitida* (Stapf) Th. & H. Dur., etc. *Ricinodendron heudelotii* (Baill.) Heckel had the highest IVI value of 36.08, 30.93, 18.04 and 13.58 % for the disturbed areas of Oluwa forest reserve, undisturbed portion of Idanre forest reserve, undisturbed areas of Oluwa forest reserve and undisturbed areas of Oluwa forest reserve, respectively.

Table 1: Growth parameters and species diversity indices of tree species in the disturbed Land Use Class in Idanre Forest Reserve

SN	Family	Species	Freq.	MDbh (cm)	T/ha	BA/ha (m^2)	RD (%)	RDO (%)	IVI (%)	Diversity Status
A		**Seedlings and Sapling**								
1	Tiliaceae	*Grewia pubescens* P. Beauv.	4	2.7	2500	1.44	3.88	0.02	0.04	2
2	Apocynaceae	*Rauvolfia vomitoria* Afzel.	2	3.9	2500	2.99	1.94	0.05	0.04	4
3	Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC.	1	4.1	2500	3.3	0.97	0.05	0.02	5
4	Asteraceae	*Vernonia amygdalina* Delile	4	5	1926	2.49	3.88	0.09	0.17	2
5	Ebenaceae	*Diospyros monbuttensis* Gürke	11	5.6	1857	1.2	10.68	0.19	1.04	1
6	Annonaceae	*Cleistopholis patens* (Benth.) Engl. & Diels	1	7.6	204	0.93	0.97	0.17	0.08	5
7	Tiliaceae	*Grewia glabra* Blume	1	7.6	204	0.93	0.97	0.17	0.08	5
8	Loganaceae	*Anthocleista liebrechtsiana* De Wild. & T. Dur.	11	8.2	413	1.49	10.68	0.21	1.12	1
9	Moraceae	*Ficus exasperata* Vahl	5	8.7	204	1.25	4.85	0.23	0.56	1
10	Pandaceae	*Microdesmis puberula* Hook. f. ex Planch.	2	9.3	204	1.37	1.94	0.25	0.25	4
11	Sterculiaceae	*Margaritaria discoidea* (Baill.) G.L. Webster var.	1	9.3	204	1.39	0.97	0.26	0.12	5
12	Sapindaceae	*Blighia unijugata* Baker	1	9.8	204	1.54	0.97	0.28	0.14	5
B		**Adult Trees**								
13	Lecythidaceae	*Napoleona imperialis* P. Beauv.	2	13.2	110	0.5	1.94	0.7	0.68	4
14	Euphorbiaceae	*Spondianthus preussii* Engl. var. preussii	6	15.1	907	1.89	5.83	1.11	3.24	1
15	Papilionoideae	*Baphia nitida* Load.	3	18.1	79	0.82	2.91	1.11	1.61	3
16	Apocynaceae	*Picralima nitida* (Stapf) Th. & H. Dur.	3	18.3	79	0.68	2.91	1.23	1.79	3
17	Detarioideae	*Anthonotha macrophylla* P. Beauv.	8	19.3	374	1.78	7.77	1.29	5.02	1
18	Verbenaceae	*Vitex grandifolia* Gürke	1	20.2	16	0.51	0.97	1.21	0.59	5
19	Papilionoideae	*Baphia pubescens* Hook. F	1	23.4	16	0.69	0.97	1.62	0.79	5
20	Euphorbiaceae	*Macaranga barteri* Müll.Arg.	1	24.1	16	0.73	0.97	1.72	0.83	5
21	Moraceae	*Musanga cecropioides* R.Br.	3	24.1	16	0.74	2.91	1.75	2.55	3
22	Apocynaceae	*Alstonia congensis* Engl.	3	24.8	79	2.09	2.91	1.96	2.85	3
23	Rutaceae	*Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler	3	26.6	16	0.89	2.91	2.09	3.04	3
24	Euphorbiaceae	*Antidesma laciniatum* Müll. Arg.	6	27.1	77	1.9	5.83	2.6	7.57	1
25	Flacourtiaceae	*Homalium letestui* Pellegr.	1	27.2	16	0.93	0.97	2.19	1.06	5

26	Sterculiaceae	*Sterculia tragacantha* Lindl.	2	27.3	16	0.94	1.94	2.2	2.14	4
27	Meliaceae	*Trichilia heudelotii* Planch. ex Oliv.	1	28.8	16	1.04	0.97	2.45	1.19	5
28	Apocynaceae	*Alstonia boonei* De Wild.	2	29.7	16	1.11	1.94	2.6	2.52	4
29	Papilionoideae	*Amphimas pterocarpoides* Harms	1	32.9	16	1.36	0.97	3.2	1.55	5
30	Tiliaceae	*Desplatsia dewevrei* (De Wild. & Th. Dur.)	2	36.3	12	1.12	1.94	4.16	4.04	4
31	Malvaceae	*Ceiba pentandra* (L.) Gaertn.	1	36.6	16	1.68	0.97	3.96	1.92	5
32	Sterculiaceae	*Sterculia rhinopetala* K. Schum	1	37.6	16	1.78	0.97	4.18	2.03	5
33	Euphorbiaceae	*Uapaca heudelotii* Baill.	3	39.3	13	1.59	2.91	4.58	6.68	3
34	Euphorbiaceae	*Ricinodendron heudelotii (*Baill.) Heckel	3	40.7	76	3.01	2.91	7.12	10.37	3
35	Sterculiaceae	*Cola gigantea* A. Chev.	1	44.4	8	1.26	0.97	5.83	2.83	5
36	Sapotaceae	*Chrysophyllum albidum* G. Don	1	112.1	8	8.05	0.97	37.15	18.04	5
		Mean (M)		**23**	**415**					

NB: Diversity status; 1 =Abundant, 2 = Frequent, 3 = Occasion, 4 = Rare, 5 = Threatened tree species

Table 2: Growth parameters and species diversity indices for tree species in the disturbed Land Used Class in Oluwa Forest Reserve

SN	Family	Species	Freq.	MDbh (cm)	T/ha	BA/ha (m^2)	RD (%)	RDO (%)	IVI (%)	Diversity Status
A		**Seedling and Saplings**								
1	Lecythidaceae	*Napoleona imperialis* P. Beauv.	2	2.1	2500	0.87	2.17	0.04	0.04	3
2	Sapindaceae	*Blighia unijugata* Baker	2	2.7	2500	1.43	2.17	0.06	0.07	3
3	Apocynaceae	*Holarrhena floribunda* (G. Don) Dur. & Schinz	4	3.1	2500	1.89	4.35	0.08	0.18	1
4	Violaceae	*Rinorea brachypetala* (Turcz.) Kuntze	2	3.5	2500	2.69	2.17	0.12	0.13	3
5	Rhamnaceae	*Maesopsis eminii* Engl.	1	5.9	204	0.56	1.09	0.29	0.16	4
6	Capparidaceae	*Buchholzia coriacea* Engl.	1	6.2	204	0.62	1.09	0.32	0.18	4
7	Ebenaceae	*Diospyros dendo* Welw. ex Hiern	3	6.4	1735	1.9	3.26	0.6	0.98	2
8	Sterculiaceae	*Cola heterophylla* (P. Beauv.) Schott & Endl.	4	6.5	1352	2.53	4.35	0.45	0.98	1
9	Rubiaceae	*Rothmannia whitfieldii* (Lindl.) Dandy	2	7.8	204	0.99	2.17	0.52	0.57	3
10	Papilionoideae	*Baphia nitida* Load.	3	7.9	1735	2.83	3.26	0.92	1.5	2
11	Apocynaceae	*Picralima nitida* (Stapf) Th. & H. Dur.	5	8.5	663	1.98	5.43	0.66	1.78	1
12	Papilionoideae	*Desmodium adscendens* (Sw.) DC. var. adscendens	1	9.4	204	1.42	1.09	0.74	0.4	4
B		**Adult Trees**								
13	Euphorbiaceae	*Macaranga hurifolia* Beille	1	11.3	204	2.05	1.09	1.07	0.58	4
14	Euphorbiaceae	*Tetrorchidium didymotemon* (Baill.) Pax & K.	2	11.5	204	2.21	2.17	1.16	1.26	3
15	Moraceae	*Ficus mucuso* Welw. ex Ficalho	1	17.3	204	4.8	1.09	2.52	1.37	4
16	Apocynaceae	*Funtumia elastica* (Preuss) Stapf	5	17.9	91	1.31	5.43	2.98	8.08	1
17	Euphorbiaceae	*Ricinodendron heudelotii* (Baill.) Heckel	21	18.4	132	2.37	22.83	3.16	36.08	1
18	Ulmaceae	*Celtis zenkeri* Engl.	1	19.3	204	5.97	1.09	3.13	1.7	4
19	Rubiaceae	*Dictyandra arborescens* Welw. ex Hook. F	2	20	204	6.41	2.17	3.36	3.66	3
20	Sterculiaceae	*Sterculia tragacantha* Lindl.	4	20.8	63	1.26	4.35	3.78	8.21	1
21	Verbenaceae	*Vitex rivularis* Gürke	1	22.7	16	0.65	1.09	4.33	2.36	4

22	Euphorbiaceae	*Macaranga barteri* Müll. Arg.	1	23	16	0.66	1.09	4.45	2.42	4
23	Anacardiaceae	*Lannea welwitschii* (Hiern) Engl.	3	23.6	16	0.7	3.26	4.7	7.67	2
24	Bignonaceae	*Stereospermum acuminatissimum* K. Schum	2	24.7	16	0.78	2.17	5.19	5.64	3
25	Cecropiaceae	*Myrianthus arboreus* P. Beauv.	1	25.4	16	0.81	1.09	5.43	2.95	4
26	Bignonaceae	*Markhamia tomentosa* (Benth.) K. Schum.	1	26.1	16	0.86	1.09	5.73	3.11	4
27	Ulmaceae	*Celtis mildbraedii* Engl.	3	26.7	16	0.92	3.26	6.18	10.07	2
28	Sterculiaceae	*Cola gigantea* A. Chev. var. gigantean	2	28.5	16	1.04	2.17	6.94	7.55	3
29	Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb.	1	28.7	16	1.04	1.09	6.93	3.76	4
30	Meliaceae	*Trichilia heudelotii* Planch. ex Oliv.	4	28.8	16	1.07	4.35	7.15	15.55	1
31	Moraceae	*Musanga cecropioides* R.Br.	4	28.9	16	1.06	4.35	7.07	15.37	1
32	Sterculiaceae	*Sterculia rhinopetala* K. Schum	2	32.4	12	0.89	2.17	9.94	10.81	3
		Mean		**16.4**	**556**					

NB: Diversity status; 1 =Abundant, 2 = Frequent, 3 = Occasion, 4 = Rare, 5 = Threatened tree species

Table 3: Growth parameters and species diversity indices for trees in the undisturbed Land use Class of Idanre Forest Reserve

SN	Family	Species	Freq.	T/ha	MDbh (cm)	BA/ha (m^2)	RD (%)	RDO (%)	IVI (%)	Diversity Status
A		**Seedlings and Saplings**								
1	Polyganaceae	*Carpolobia lutea* G. Don	1	204	6.4	0.66	1	0.11	0.05	4
2	Ebenaceae	*Diospyros dendo* Welw. ex Hiern	1	204	6.4	0.66	1	0.11	0.05	4
3	Sterculiaceae	*Cola heterophylla* (P. Beauv.) Schott & Endl.	3	204	9.1	1.4	3	0.23	0.34	2
4	Rubiaceae	*Rothmannia whitfieldii* (Lindl.) Dandy	1	204	9.4	1.42	1	0.23	0.11	4
5	Detarioideae	*Anthonotha macrophylla* P. Beauv.	8	1592	9.5	1.35	8	0.52	2.07	1

B			Adult Trees							
6	Annonaceae	*Cleistopholis patens* (Benth.) Engl. & Diels	2	204	12.6	2.75	2	0.44	0.44	3
7	Euphorbiaceae	*Croton penduliflorus* Hutch.	1	204	15.8	4	1	0.64	0.32	4
8	Apocynaceae	*Funtumia elastica* (Preuss) Stapf	5	129	16.2	1.31	5	0.85	2.12	1
9	Anacardiaceae	*Lannea welwitschii* (Hiern) Engl.	1	204	17.9	5.14	1	0.83	0.41	4
10	Irvingiaceae	*Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke)	2	110	18.4	1.93	2	0.91	0.91	3
11	Ulmaceae	*Trema orientalis* (L.) Blume	1	204	18.4	5.43	1	0.87	0.44	4
12	Phyllanthaceae	*Malacantha alnifolia* (Bak.) Pierre	3	139	19.1	0.82	3	1.84	2.76	2
13	Fabaceae	*Dialium guineense* Willd.	1	204	19.4	6.03	1	0.97	0.49	4
14	Burseraceae	*Canarium schweinfurthii* Engl.	1	204	20	6.41	1	1.03	0.52	4
15	Annonaceae	*Hexalobus crispiflorus* A. Rich.	1	204	20	6.41	1	1.03	0.52	4
16	Caesalpiniaceae	*Hylodendron gabunense* Taub.	2	110	20	2.77	2	1.05	1.05	3
17	Rutaceae	*Zanthoxylum zanthoxyloides* (Lam.) Zepern.	1	16	20.2	0.51	1	1.05	0.53	4
18	Papilionoideae	*Baphia nitida* Load.	3	79	21.3	1.72	3	1.22	1.83	2
19	Ulmaceae	*Celtis zenkeri* Engl.	4	110	21.6	2	4	1.51	3.03	1
20	Verbenaceae	*Vitex grandifolia* Gürke	1	16	22.9	0.66	1	1.35	0.68	4
21	Sterculiaceae	*Sterculia tragacantha* Lindl.	2	16	23	0.67	2	1.37	1.37	3
22	Ulmaceae	*Celtis philippensis* Blanco	1	16	24.3	0.74	1	1.52	0.76	4
23	Moraceae	*Musanga cecropioides* R.Br.	8	374	27.5	2.5	8	2.37	9.49	1
24	Moraceae	*Ficus exasperata* Vahl	2	16	28.5	1.04	2	2.14	2.14	3
25	Euphorbiaceae	*Ricinodendron heudelotii* (Baill.) Heckel	19	155	32.1	1.49	19	3.26	30.93	1
26	Sapotaceae	*Mansonia altissima* (A.Chev.) A.Chev.	2	12	32.8	0.92	2	2.99	2.99	3
27	Apocynaceae	*Picralima nitida* (Stapf) Th. & H. Dur.	3	13	36.2	1.31	3	3.79	5.68	2
28	Combretaceae	*Terminalia ivorensis* A.Chev.	1	16	36.3	1.66	1	3.4	1.7	4
29	Sterculiaceae	*Sterculia rhinopetala* K. Schum	5	13	36.8	1.27	5	3.67	9.17	1
30	Dracaenaceae	*Dracaena arborea* (Willd.) Link	2	16	37.9	1.81	2	3.71	3.71	3
31	Detarioideae	*Hymenostegia afzelii* (Oliv.) Harms	2	12	39.5	1.36	2	4.13	4.13	3

32	Mimosoideae	*Albizia zygia* (DC.) J.F. Macbr	1	8	40.6	1.06	1	4.25	2.13	4
33	Fabaceae	*Pterocarpus macrocarpus* Kurz	2	12	43.2	1.59	2	5.54	5.54	3
34	Meliaceae	*Trichilia lanata* A. Chev.	1	8	44.3	1.26	1	5.06	2.53	4
35	Fabaceae	*Pterocarpus osun* Craib	1	8	45	1.3	1	5.22	2.61	4
36	Lecythidaceae	*Napoleona imperialis* P. Beauv.	2	106	47.5	5.01	2	7.77	7.77	3
37	Anacardiaceae	*Pseudospondias microcarpa* (A. Rich.) Engl.	1	8	51	1.67	1	6.71	3.35	4
38	Euphorbiaceae	*Discoglypremna caloneura* (Pax) Prain	1	8	54.3	1.89	1	7.61	3.8	4
39	Combretaceae	*Terminalia superba* Engl. & Diels	1	8	58	2.16	1	8.68	4.34	4
		Mean		**138**	**27.3**					

NB: Diversity status; 1 =Abundant, 2 = Frequent, 3 = Occasion, 4 = Rare, 5 = Threatened tree species

Table 4: Growth parameters and species diversity indices for tree species in the undisturbed Land Use Class in Oluwa Forest Reserve

SN	Family	Species	Freq.	MDbh (cm)	T/ha	BA/ha (m^2)	RD (%)	RDO (%)	IVI (%)	Diversity Status
A		**Seedlings and Saplings**								
1	Euphorbiaceae	*Croton penduliflorus* Hutch.	1	7	204	0.79	1.23	0.41	0.25	4
2	Papilionoideae	*Baphia pubescens* Hook. F	2	7.5	204	0.91	2.47	0.47	0.58	3
3	Moraceae	*Ficus mucuso* Welw. ex Ficalho	1	8.3	204	1.10	1.23	0.57	0.35	4
4	Rubiaceae	*Dictyandra arborescens* Welw. ex Hook. F	2	8.7	204	1.23	2.47	0.64	0.79	3
5	Rubiaceae	*Rothmannia whitfieldii* (Lindl.) Dandy	2	8.9	204	1.28	2.47	0.66	0.82	3
B		**Adult Trees**								
6	Euphorbiaceae	*Antidesma laciniatum* Müll. Arg. var. laciniatum	1	10.0	204	1.60	1.23	0.83	0.51	4
7	Moraceae	*Ficus exasperata* Vahl	3	10.6	204	2.17	3.70	1.12	2.08	2
8	Papilionoideae	*Baphia nitida* Load.	10	11.0	204	2.04	12.35	1.06	6.52	1
9	Bignonaceae	*Newbouldia laevis* (P. Beauv.) Seemann. ex Bureau	1	11.1	204	1.97	1.23	1.02	0.63	4
10	Olacaceae	*Strombosia pustulata* Oliv. var. pustulata	3	11.3	204	2.63	3.70	1.36	2.53	2
11	Ulmaceae	*Trema guineensis* (Schum. & Thonn.) Ficalho	1	11.5	204	2.12	1.23	1.10	0.68	4
12	Moraceae	*Treculia africana* var. mollis (Engl.) J. Léonard	2	12.2	204	2.37	2.47	1.23	1.52	3
13	Ulmaceae	*Celtis zenkeri* Engl.	1	12.8	204	2.63	1.23	1.36	0.84	4
14	Moraceae	*Ficus sur* Forssk.	1	13.2	204	2.79	1.23	1.45	0.89	4
15	Rubiaceae	*Hunteria umbellata* (K. Schum.) Hallier f.	2	13.2	204	3.01	2.47	1.56	1.93	3
16	Ebenaceae	*Diospyros dendo* Welw. ex Hiern	2	13.9	204	3.10	2.47	1.61	1.98	3
17	Apocynaceae	*Funtumia elastica* (Preuss) Stapf	2	14.0	204	3.22	2.47	1.67	2.06	3
18	Euphorbiaceae	*Bridelia micrantha* (Hochst.) Baill	5	15.1	588	1.82	6.17	2.35	7.25	1
19	Moraceae	*Milicia excelsa* (Welw.) C.C. Berg	1	15.2	204	3.70	1.23	1.92	1.19	4
20	Euphorbiaceae	*Tetrorchidium didymotemon* (Baill.) Pax	2	15.4	204	3.95	2.47	2.05	2.53	3
21	Moraceae	*Trilepisium madagascariense* DC.	1	15.6	204	3.90	1.23	2.02	1.25	4

22	Detarioideae	*Anthonotha macrophylla* P. Beauv.	5	15.8	166	2.47	6.17	2.61	8.06	1
23	Apocynaceae	*Picralima nitida* (Stapf) Th. & H. Dur.	5	16.0	91	0.80	6.17	2.46	7.59	1
24	Sterculiaceae	*Sterculia rhinopetala* K. Schum	1	16.8	204	4.52	1.23	2.35	1.45	4
25	Ulmaceae	*Celtis mildbraedii* Engl.	2	17.3	204	4.77	2.47	2.47	3.05	3
26	Euphorbiaceae	*Ricinodendron heudelotii* (Baill.) Heckel	11	19.7	101	1.94	13.58	3.61	24.49	1
27	Meliaceae	*Khaya grandifoliola* C. DC.	1	22.1	16	0.61	1.23	4.06	2.51	4
28	Moraceae	*Musanga cecropioides* R.Br.	3	25.7	16	0.84	3.70	5.59	10.35	2
29	Euphorbiaceae	*Discoglypremna caloneura* (Pax) Prain	2	28.4	510	1.38	2.47	9.83	12.14	3
30	Cecropiaceae	*Myrianthus arboreus* P. Beauv.	1	28.5	16	1.02	1.23	6.75	4.17	4
31	Euphorbiaceae	*Macaranga hurifolia* Beille	1	31.3	16	1.23	1.23	8.14	5.03	4
32	Rubiaceae	*Psydrax parviflora* subsp. chapmanii Bridson	2	37.7	416	1.24	2.47	12.05	14.87	3
33	Ulmaceae	*Holoptelea grandis* (Hutch.) Mildbr.	1	40.5	816	1.05	1.23	13.63	8.41	4
		Mean		**16.5**	**219**					

NB: Diversity status; 1 =Abundant, 2 = Frequent, 3 = Occasion, 4 = Rare, 5 = Threatened tree species

Tree species diversity indices

Shannon-Wiener diversity index (H) ranged between 3.03 and 3.26 for the land use classes of Idanre and Oluwa forest reserves. The disturbed portion of Idanre forest reserve had the highest Shannon-Wiener diversity index of 3.26, which was followed by that of the undisturbed land use class (3.23) of Idanre forest reserve while the lowest Shannon-Wiener diversity index value was recorded for the disturbed area land use class of Oluwa forest reserve with 3.03. The tree Pielou's species evenness obtained spanned from 0.65 to 0.73 for Idanre and Oluwa forest reserves. Pielou's species evenness value of 0.65 was recorded for undisturbed land use class of Idanre forest reserve, as the least. While the highest Pielou's species evenness value of 0.73 was recorded for undisturbed forest land use class of Oluwa forest reserve (Table 5). The values for Margalef index (M) of species diversity ranged between 6.67 and 8.25 for the LU classes of Oluwa and Idanre forest reserves (Table 5). The highest Margalef index value of 8.25 was recorded for undisturbed areas of Idanre forest reserve, which was followed by the disturbed portion of Idanre forest reserve while the lowest value (6.67) was recorded for disturbed portion of Oluwa forest reserve (Table 5).

Table 5: Species Diversity Indices across the LULC of Idanre and Oluwa forest reserves

Diversity Indices	Idanre Forest reserve		Oluwa Forest Reserve	
	Undisturbed Forest	Disturbed Forest	Undisturbed Forest	Disturbed Forest
No. of Species	39	36	33	32
No. of Individuals	100	103	81	90
Mean Tree/ha	138	415	219	556
Mean DBH	27.3	23.0	16.5	16.4
Shannon-Wiener (*H*)	3.23	3.26	3.18	3.03
Pielou's species Evenness (*En*)	0.65	0.72	0.73	0.67
Margalef index (*M*)	8.25	7.55	7.28	6.67

Discussions

Tree species composition

This study focuses on the tree species composition in the Idanre and Oluwa forest reserves. The study reported that the number of tree species varied between 32 and 39 species in both forest reserves. These species belonged to 13 and 24 tree families, depending on the land-use (LU) class and forest reserve.

The tree density in the two forest reserves was moderate, ranging from 138 to 556 stems per hectare (ha), depending on the LU class. Comparing these findings to similar studies conducted in comparable ecosystems, the results are consistent. Adekunle *et al.* (2013) reported a density of 387 stems ha^{-1} in a Strict Nature Reserve in Nigeria, Oke *et al.* (2020) reported 152 stems ha^{-1} for Oluwa Forest Reserve, and Ige and

Adekunle (2021) reported 135 stems ha-[1] for Ora Community Forest in Kwara State, Nigeria.

However, in some LU classes, the tree density in this study was higher than the aforementioned reports. This discrepancy could be attributed to the inclusion of trees with small diameter at breast height (Dbh) (≥ 2 cm) in the calculation of stand density. In most referenced studies, the minimum Dbh considered was 10 cm. Onyekwelu *et al.* (2021) also supported this claim by stating that tree density increases when lower diameter trees are included in density computation. In another study by Onyekwelu *et al.* (2022), a much higher range of tree density (1427 to 4825 ha-1) was reported for sacred groves in South-western Nigeria, where seedlings, saplings, and over story trees were included in the estimation.

The dominant tree families in the Idanre and Oluwa forest reserves were found to be Euphorbiaceae, Sterculiaceae, and Ulmaceae. These findings align with other studies conducted in South-western Nigeria's tropical rainforest ecosystems, such as Onyekwelu *et al.*, (2008), Adekunle *et al.* (2013), and Ajayi and Arowosoge (2018), where the dominant families were reported to be Sterculiaceae, Euphorbiaceae, and Meliaceae.

Conclusively, the study reveals that the Idanre and Oluwa forest reserves have a diverse tree species composition, with moderate tree density. The dominant tree families are Euphorbiaceae, Sterculiaceae, and Ulmaceae, which is consistent with similar studies conducted in the region.

Tree Species Abundance

The study identifies some tree species that were classified as abundant in the disturbed and undisturbed forest of Idanre and Oluwa forest reserves. In the disturbed forest land use class of Idanre forest reserve, tree species such as *A. macrophylla, F. exasperata, A. liebrechtsiana,* and *D. monbuttensis* were classified as abundant. Similarly, in the disturbed and undisturbed areas of Oluwa forest reserve, species like *R. heudelotii, P. nitida, F. elastic, M. cecropioides,* and *B. nitida* were classified as abundant. The *R. heudelotii* was observed as abundant in this study and this is consistent with the report of Ajayi and Arowosoge (2018) in their paper "Assessment of economic tree species diversity in Ajasin University, Akungba Akoko, Ondo State, Nigeria.

Additionally, most of the tree species identified in the study fell into the occasional and threatened categories. In Idanre and Oluwa forest reserves, some tree species were classified as threatened. Some of the threatened tree species identified in Oluwa forest reserve included *Vitex rivularis, Markhamia tomentosa, Newbouldia laevis,* and *Buchholzia coriacea*, while threatened species in Idanre forest reserve included *Pseudospondias macrocarpa, Polyathia oliver, Hexalobus crispiflorus, Terminalia ivorensis, Khaya grandifoliola, Albizia zygia, Milicia excelsa,* and *Celtis philippensis* corroborate other studies (Adeyemi *et al.*, 2015). These findings support with the results of Adeyemi *et al.* (2015), who reported some of these tree species as threatened in Okwangwo forest in Cross River State, Nigeria. Furthermore, *Milicia excelsa, Terminalia*

ivorensis, and *Khaya grandifoliola* were listed as threatened tree species on the IUCN Red List, corroborating the observations of the present study (Olajuyigbe *et al.*, 2013; Adeyemi *et al.*, 2015). The high prevalence of threatened tree species in the forest reserves can be attributed to anthropogenic activities such as logging, conversion of forest land for agriculture, and habitat destruction as reported by Oduntan *et al.* (2013). These activities have been recognized as major threats to forests in Nigeria (Onyekwelu 2008; Oduntan *et al.*, 2013). The pressure from human-induced activities has likely affected the composition and abundance patterns of tree species, leading to a high number of species in the threatened category. Though, the composition and abundance of tree species play a significant role in the status of forest ecosystems, as highlighted by Adeyemi *et al.* (2015).

Tree Species Diversity

Tropical rainforest ecosystems contain important diversity of species, genetic resources and ecological processes (Ige and Adekunle, 2021). The tropical rainforest ecosystems in Idanre and Oluwa forest reserves are known to possess a significant diversity of species, genetic resources, and ecological processes, as mentioned by Ige and Adekunle (2021). Various measures are used to assess species diversity, including species richness, Pielou's species evenness, Margalef's index, Simpson concentration, Shannon-Wiener diversity index, among others, as stated by Gonçalves *et al.* (2017). The Shannon-Wiener diversity index typically ranges from 1.5 to 4.0 and rarely exceeds 4.5 (Kent and Coker, 1992). A lower value indicates a site with fewer species and a few dominant tree species, while a higher value signifies a considerably diverse tree species assemblage (Magurran, 2004).

In this study, the estimated Shannon-Wiener diversity index values ranged from 3.03 to 3.26 for the different land-use classes (LU) in Idanre and Oluwa forest reserves, indicating moderate tree species diversity and relatively few dominant trees. These values were lower than the findings of Ogundele *et al.*, (2021), who reported a Shannon-Wiener diversity index value of 3.37 for Akure Forest Reserve in Nigeria. Onyekwelu *et al.* (2022) reported diversity index values ranging from 2.65 to 3.55 for four sacred groves in south-western Nigeria, which were lower, comparable, or higher than the values from this study. The Shannon-Wiener diversity index value of 3.74 reported by Adekunle *et al.* (2013) for a Nigerian Strict Nature Reserve was higher than the values obtained in this study.

The Pielou's species evenness index ranges from 0 to 1, with 1 indicating that all species have an equal distribution across the ecosystem (Kanieski *et al.*, 2010). The estimated Pielou's species evenness index values ranged from 0.65 to 0.73 for the different LU classes in Idanre and Oluwa forest reserves, indicating a relatively similar distribution of tree species. These values were lower than the value of 0.82 reported by Ogundele *et al.* (2021) for tree species in Akure Forest Reserve. The result of Pielou's species evenness of 0.68 reported by Adekunle *et al.* (2013) for a Strict Nature Reserve in Akure, Nigeria,

was comparable to the results of this study. Other studies, such as Onyekwelu *et al.* (2008), and Agbelade and Ojo (2020), have reported lower Pielou's species evenness values ranging from 0.45 to 0.66 for natural forests in South-western Nigeria. The low Pielou's species evenness observed in this study suggests variation in the distribution of tree species throughout the different land-use systems and forest reserves.

The Margalef index value is zero when all trees in the forest belong to a single species, and the value increases as the number of species (i.e., species richness) increases (Adekunle *et al.*, 2013; Sina and Zulkarnaen, 2019). In this study, the Margalef index values for the different land-use classes in Idanre and Oluwa forest reserves ranged from 6.67 to 8.25. These values were lower than the reported Margalef index of 8.562 for woody tree species in Ora Community Forest, Kwara State, Nigeria, by Ige and Adekunle (2021). Additionally, the results were lower than the Margalef's value of 14.69 reported by Ajayi and Arowosoge (2018) for assessment of economic tree species diversity in Adekunle Ajasin University, Akungba Akoko, Nigeria. The low Margalef's values obtained in this study further indicate a moderate number of tree species, potentially influenced by anthropogenic activities in these forest reserves.

Totally, the results suggest that Idanre forest reserve exhibited higher biodiversity values in various indices compared to Oluwa forest reserve, including higher Shannon-Wiener diversity, Margalef's index, stems per hectare, and mean tree values. Though, these forest reserves are considered potential biodiversity hotspots that require improved conservation and management efforts.

Conclusion

The findings of this study indicate that the biodiversity indices assessed in the two land-use classes within Idanre and Oluwa forest reserves were generally low to moderate. This could be attributed to the presence of anthropogenic activities in the forest reserves, which may have had an impact on the biodiversity levels. There were variations in the parameters studied when compared to some previous researches; the notable observations from this study align well with other studies conducted in similar forest communities.

Furthermore, the dominant tree species in both forest reserves included *Diospyros monbuttensis, Anthocleista liebrechtsiana, Ricinodendron heudelotii,* and *Baphia nitida*, which are commonly found in the tropical rainforests of South-western, Nigeria. The dominant families observed in the forest reserves were Euphorbiaceae, Sterculaceae, Ebenaceae, and Apocynaceae. It is worth noting that a high percentage of the tree species found in the study sites were classified as threatened and listed in the IUCN Red List. This could be attributed to anthropogenic activities or the management strategies employed in the forest reserves.

The results emphasize the importance of implementing strict conservation policies to protect the valuable biodiversity resources present in Idanre and Oluwa forest reserves. These reserves hold significant potential for biodiversity conservation if adequately maintained and protected.

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Authors Contributions

All authors contributed to the study conception and design of this manuscript. Material preparation, data collection and analysis were performed by Ezekiel AJAYI, Jonathan C. ONYEKWELU and Shadrach O. AKINDELE. The first draft of the manuscript was written by Ezekiel AJAYI and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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