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ASSESSMENT OF TRAINING NEEDS ON AGROCHEMICAL SAFETY MEASURES AMONG CROP FARMERS IN SOUTHERN AGRICULTURAL ZONE OF NASARAWA STATE, NIGERIA

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ABSTRACT

The study assessed the training needs of agrochemical safety measures among crop farmers in the Southern Agricultural Zone of Nasarawa State, Nigeria. Multistage sampling procedure was used to draw 220 respondents. Copies of structured questionnaire were administered to obtain data for the study. Analysis of data was done using descriptive statistics. The result on socioeconomic characteristics of the respondents revealed that many (46.82%) were in the age range of 33-47 years, majority (74.55%) were male, 70.91% were married, 74.55% had formal education, 68.64% had 1-10 household size, 60.45% had 1-5 hectares of farmland, 72.27% had contact with extension agents, and 64.55% were non-members of cooperative societies. Correct use of knapsack sprayer (89%), cleaning chemical during accident (83%), right type of chemical to use (78%), and appropriate mixing/dilution of agrochemicals (67%) were the areas that farmers needed training to enhance safe use of agrochemicals. The major constraints of the respondents to agrochemical safety practices in the area were inadequate fund (90%), inadequate skills/equipment (76%), and inappropriate mixing/dilution of chemicals (64%). It was recommended that regular extension visit should be intensified with focus on addressing areas that farmers need training on the safe use of agrochemicals.

Keywords: Agrochemicals, Safety, Training needs, Crop farmers

INTRODUCTION

Agriculture is a key sector of Nigeria economy that contributed 22.36% to overall of the Gross Domestic Product (GDP) in first quarter of 2022 (National Bureau of Statistics, NBS, 2022) and employs about 34.97% of the country's working population (Doris, 2022). It is also the largest economic activity in the rural areas where almost fifty percent of the population lives, and the main source of livelihood for most Nigerians (Food and Agriculture Organization, FAO, 2020). The major source of crop production in the country is the subsistence farmers, which acconted for 90% of the staples produced and consumed in the country. The major staple food crops produced in the country include rice, maize, guinea corn, yam, cassava, millet, cowpea, groundnut, and sweet potato. These crops are often produced with the aid of inorganic chemicals.

In Nigeria, agrochemicals are used for many farming activities which include the control of weed, pests, improve crop growth and enhance increased output. The chemicals are vital in both pre-harvest and post-harvest food management in the country by ensuring sustainable food production. Pesticide as an agrochemical, is a chemical substance that is used for preventing, destroying, repelling or mitigating the effects of pest of plants and animals (NAFDAC, (1996). It includes insecticides, fungicides, herbicides, rodenticides, molluscides, nematicides, avicides, acaricides, repellents, and attractants used in agriculture, public health, horticulture, and food storage. Forty-five percent of total production can be lost to diseases and pests without application of agrochemicals (Tijani, 2006).

Agrochemical substances are in different forms. These include powders, granules, liquids, or gases. Majority of them are poisonous or harmful to man, animals, and the environment because of their toxic and corrosive nature. Sajo and Mustapha (2007) discovered that agrochemical hazards on human health and on the environmental is as a result of misuse, starting from the point of buying, applying, storage, to disposing wastes and containers. They emphasized that risks associated with agrochemicals application can be reduced if farmers adhere to the guidelines of the precautionary measures. Training of farmers on the safety precautions is therefore required.

Training is a method by which an individual becomes developed in knowledge, skills, and attitudes that arerequired to carry out assigned task effectively (Michel, 2001). While training needs are considered as skill, knowledge and attitude possessed by individuals to overcome difficulties and avoid creating problematic situations (Owona *et al*., 2010).

Farmers who have little or no knowledge on the appropriate use of agrochemicals often make wide use of these chemicals in their farm operations and the indiscriminate use may result to air, water, and soil pollution which causes much residues on food crop and contamination of drinking water. Pesticides are known to penetrate into the blood system of human through the eyes, nose, mouth, and skin. Exposure of farmers to this chemicals can result in acute or chronic health conditions (USEPA, 2007).

Many crop farmers are found to have inadequate knowledge and information on the health implications of handling and using agrochemicals; hence, negleting the use of protective clothings and some precautionary measures. Thereby, exposing them to chemicals that may results to health complications such as skin problems, convulsion, dizziness, headaches, abdominal pain, loss of memory etc. Training in the use of agrochemicals is therefore relevant to farmers to ensure safety in chemical application without causing harm to oneself, other people, and the environment. The study assessed the training needs of agrochemicals safety measueres in the Southern Agricultural zone of Nasarawa State.

Specific Objectives

i. Describe socioeconomic characteristics of the respondents;
ii. Assess the training needs on agrochemical safety measures; and
iii. Identify constraints to agrochemical safety measures.

METHODOLOGY

The study was conducted in Southern Agricultural zone of Nasarawa State, Nigeria. The zone is made up of five Local Government Areas (LGAs) which include Awe, Doma, Keana, Lafia, and Obi LGAs.

Farming is the major occupation of the people in the zone. Crops grown in the zone include yam, maize, rice, cowpea groundnut, melon, sesame, millet, soya beans, and cassava. The State lies between latitude 7^o45'N and 9^o 25'N of the equator and between longitude 7^oE and 9^o25'E of the Greenwich meridian. The average annual rainfall is about 1,200 mm 2,000 mm per annum and the annual temperature ranges from 25^oC-27.5^oC.

The target population of this study comprises crop farmers that use agrochemicals in the study area. Multistage sampling procedure was used in drawing the sample from the population. At the first stage, random selection of 3 LGAs out of five LGAs in the zone was made. At the second stage, there was a random selection of 3 villages from each of the 3 selected LGAs making a total of 9 villages; and finally, a random selection of 20% of respondents based on the sampling frame was carried out to give a sample size of 220.

Primary data were collected with the aid of questionnaire and analyzed using descriptive statistics such as frequency, percentages, ranking and mean to achieve the specific objectives of the study.

RESULTS AND DISCUSSION.

Socio-Economic Characteristics of the Respondents

Table 2 revealed that many (46.82%) of the farmers were between the age of 33 and 47 years, with age mean of 40 years. This depicts that majority of the respondents were in their energetic and active age in which they can carry out safety agrochemical practices. The result agreed with Maryam *et al*. (2019) who reported an average age of 48.15% of the respondents, stating that the farmers were in their youthful age and actively involved in agrochemical safety practices. The result on gender revealed that 74.55% of the farmers were male. Implying that men were more into crop farming than women and hence, they tend to use agrochemical more than female crop farmers in the area. This finding is similar to that of Nyatuame and Ampiaw (2015), Maryam *et al.* (2019), Tanko *et al.* (2018), Jamala *et al.* (2013) and Eifediyi *et al.* (2014) who revealed that the majority of farmers that were involved in agrochemical practices were male. The majority (70.91%) of the farmers were married. It is generally believed that married people have more responsibility to cater for their family than singles therefore they tend to engage in some livelihood activities, such as farming. This is in agreement with Tanko *et al.* (2018), who observed that 80% of the farmers in Bali LGA of Taraba State were married.

The finding also revealed that majority (74.55%) of the respondents had one form of education or the other. Education plays a vital role in helping the farmers to identify their areas of training needs thereby, making it possible for desired training programmes to be organised. Ekewmpu and Anderson (2019), Tanko *et al.* (2018), and Jamala *et al.* (2013) reported a similar finding in their study, revealing that majority of the respondents involved in agrochemical practices attended one form of education or the other. The result of this study further shows that many (68.64%) of the respondents had between 1 and 10 persons as household size. The average household size of the respondents was 8 persons. Household size is assumed to represent the labour input of the farm. The result imply an average number of household size, which can render family labour in carrying out crop production operations such as agrochemical application on the farm. This is in agreement with Tanko *et al*. (2018) who revealed that majority of the farmers in Bali LGA of Taraba State, had household size of 1-10 person(s). Many (60.45%) of the respondents cultivated between 1 and 5 hectares of land, with the mean farm size of 4 ha. This implies that crop farmers in the study area were smallholder farmers. The result is contrary to Jamala *et al*. (2013) who reported that majority of the respondents in Guyuk, Adamawa State, had farm sizes of less than 1 ha. The larger the farm size, the more likelihood it is for the application of agrochemicals in farm operations.

Further more, the result shows that many (44.09%) of the respondents had farming experience of between 11 and 20 years, with the mean of 16 years. This shows that majority of the farmers were into crop production for many years and as such are very much farmiliar with farming operations. The long-year experience is expected to increase the ability and courage of the farmer to adopt measures that would guarantee their safety and as well increase their output/income level. The the result concur with Maryam *et al.* (2019) alongside Ekwempu and Anderson (2019) who reported that majority of the farmers in their areas of study, had farming experience of between 11-20 years with the use of agrochemicals. Results on the annual income of the farmers shows that most (69.10%) earned within the range of ₦ 0.1 million to ₦1 million. The mean annual income of the respondents was ₦673,418. The finding also revealed that majority (72.27%) of the farmers had contact with extension agents for at least once in a year. Extension contact as a major source of disseminating new agricultural technologies to farmers is encouraging, as majority of the respondents in the area had access to extension and as such had a better opportunity to be educated about safety precautions regarding agrochemical usage. The result on extension contact is contrary to Ogunjimi and Farinde (2012) who revealed that 65% of the respondents in Osun State and 96.6% in Edo State had no any visit by the extension agents, whom are suppose to enlightened the farmers on the need to adopt precautionary measures of using agrochemicals.

Finally, results on membership of cooperative society show that 65% of the crop farmers were non-members of cooperative societies. This implies that the majority of the respondents do not belong to any cooperative society which could probably be attributed to absence/inadequacy of farmers' cooperative association in the area. Being a member of cooperative societies could give farmers some privileges to access loan and farm inputs like agrochemicals easily from the government and other donor agencies; it could also help farmers in interacting with one another to share basic knowledge like the safe use of agrochemicals.

Areas of Respondents' Training Needs

The results in Table 3 show that majority (89%) of the respondents were highly in need of training on the proper use of knapsack sprayer, 83% needed training on the administration of first aid on victims of agrochemical poison, 78% required knowledge on the appropriate agrochemical to apply, while 67% required training on appropriate mixing/dilution of agrochemicals. This finding is in line with Umar *et al*. (2013) who reported the use of knapsack sprayer, type of agrochemical to apply, mixing of agrochemicals and cleaning of agrochemicals among others, as the areas farmers' desire training on the safe use of agrochemical.

Constraints to Agrochemicals Safety Measures

Table 4 revealed the constraints to agrochemical safety measures by the respondents. The major constraints identified by the respondents were inadequate fund ranking 1st, inadequate skills and equipment ranking 2nd, inappropriate mixing/dilution of chemical ranking 3rd, dangers of agrochemical ranked 4th, and poor knowledge of correct agrochemical to use ranking 5th. The result is in line with that of Jamala *et al*. (2013) who revealed inadequate fund, difficulty in application of agrochemicals, inadequate skills/equipment, among others as the reason for low adoption of agrochemical safety measures.

Table 2: Distribution of the respondent according to their socio-economic attributes (n=220)

Factor	Frequency	Percentage	Mean
Age			
18-32	61	27.73	40
33-47	103	46.82	
Above 47	56	25.45	
Gender			
Male	164	74.55	
Female	56	25.45	
Marital Status			
Married	156	70.91	
Single	64	29.09	
Educational Level (Years)			
None	56	25.45	
Primary	41	18.64	
Secondary	69	31.40	
Tertiary	54	24.51	
Household Size (Number)			
1-10	151	68.64	8
11-20	56	25.45	
Above 20	13	5.91	
Farm Size (ha)			
<1	42	19.09	4
1-5	133	60.45	
6-10	39	17.73	
> 10	6	2.73	
Farming experience (Years)			
1-10	82	37.27	16
11-20	97	44.09	
Above 20	41	18.64	
Income (Naira)			
< 0.1m	25	11.36	₦673,418
0.1m-1m	152	69.10	
1.01m-2m	35	15.90	
> 2m	8	3.64	
Extension contact (Number)			
No contact	61	27.73	
1-5	71	32.27	
6-10	33	15.00	
Above 10	55	25.00	
Membership of Cooperative			
Non-Member	142	64.55	
Members	78	35.45	

Source: Field survey, 2021

Table 1: Sampling frame of the study

Southern zone	Selected LGAs	Selected villages	Registered farmers	No. of Respondents (20%)
	Doma	Doma	200	40
		Rukubi	100	20
		Burumburum	80	16
	Obi	Obi	180	36
		Tudun-adabu	95	19
		kadunan koro	115	23
	Lafia	Maraban-akunza	110	22
		Akurba	120	24
		Adogi	100	20
Total	3	9	1100	220

Table 3: Distribution of respondents based on their areas of training needs

Variables	Frequency	Percentage
Proper use of knapsack sprayer	195	89
Cleaning chemical during accident	182	83
Right type of chemical to use	171	78
Appropriate mixing/dilution of chemical	148	67
Proper disposal of agrochemical container	125	57
Application time	112	51
Storage of chemicals	103	47
Use of PPEs	84	38

Source: Field Survey, 2021
Multiple Responses

Table 4: Distribution of respondents based on their constraints to adoption of agrochemical safety measures

Constraints	*Frequency	Percentage	Ranking
Inadequate fund	197	90	1st
Inadequate skills and equipment	168	76	2nd
Inappropriate dilution/mixing of chemicals	141	64	3rd
Dangers of agrochemicals	139	63	4th
Poor knowledge of correct agrochemical to use	135	61	5th
Inconveniences of wearing PPEs	129	59	6th
Offensive odour of chemicals	111	50	7th
Absence of reputable agrochemical dealers	107	49	8th
Illiteracy of farmers	89	40	9th
Poor extension contact	79	36	10th

Source: Field Survey, 2021
* Multiple Responses

CONCLUSION AND RECOMMENDATION

The major areas of training needs of the respondents on the safe use of agrochemicals include: proper use of knapsack sprayer, cleaning of agrochemicals during accidents, knowledge on the right type of agrochemical, and appropriate mixing of chemicals. Inadequate funds, inadequate skills and equipment, inappropriate mixing/dilution of chemicals, the danger of agrochemicals, and poor knowledge of correct agrochemical to use were the major constraints to agrochemical safety measures identified by the respondents in the study area. It was recommended that:

Regular extension visit should be intensified with focus on training needs such as proper use of knapsack sprayer, cleaning chemicals during accidents, and appropriate mixing/dilution of chemicals; also, farmers should be enlightened by the extension agents on the need to use personal protective equipment which is aimed at reducing the extent of exposure to chemicals and minimizing health hazards.

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ANALYSIS OF PROFITABILITY AND TECHNICAL EFFICIENCY IN LAYERS PRODUCTION IN THE NORTH-CENTRAL NIGERIA

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ABSTRACT

The study carried out analysis of profitability and technical efficiency in layers production in the North-central Nigeria. A multistage sampling technique was used to select 156 respondents for the study. Data for the study were collected using structured questionnaires complemented with a personal interview schedule. Data were analyzed using Gross margin and Cobb-Douglas stochastic frontier production model. The findings indicate that layer farmers recorded Gross margin of ₦1,247,026 per 603 birds per production cycle. Cost of feed constituted 97% of total variable cost of production. The coefficients of the variables of initial stock (0.654; P<0.05); medication (0.104; P<0.05) and labour (0.246; P<0.05) were significantly influencing the output of egg production. The poultry enterprise was characterized by return to scale, though the farmers were largely operating below technical efficiency frontier of 0.72. The coefficients of farmers' age (-1.926; P<0.05) and level of education (-1.942; P<0.05) had significant influence in enhancing farmers' efficiency. High cost of feed, incidence of disease and high mortality rate were major challenges confronting layer farmers in the study area. It is therefore recommended that all stakeholders in the poultry value chain businesses should come together to deliberate how best to curtail the spirally rise in price of poultry feeds in the country. Addressing this problem has potential of increasing significantly the fortunes in the poultry enterprise. Also, Poultry farmers should be encouraged to form a cooperative organizations in order to enjoy the economies of scale in the purchase of input like feed. Both private and public extension agents should be encouraged to visit the poultry farmers regularly to proffer appropriate guidance in improving the efficiency of production.

Keywords: Profitability, Technical Efficiency, Poultry (Egg) Production, North-central

INTRODUCTION

Poultry are birds of economic value to man in the provision of meat, egg and fibre (such as feathers) which can be used in making pillows, mattresses, shuttle cork (bridle) for badminton (Saliu, 2013; Saliu *et al*., 2015). Poultry apart from supplying protein is also a good source of lipids and vitamins of high zoological value to man (Bamiro, *et. al*, 2006). Laseinde (2000) described the types of poultry that are commonly reared in Nigeria to include: chickens, ducks, guinea fowls, turkeys, pigeons and more recently ostriches and Japanese quail. Poultry such as chickens, guinea fowl and turkeys dominate the poultry enterprise. According to Ojo (2003), poultry keeping has the following advantages over other livestock: poultry birds are good converters of feeds into usable protein in meat and eggs; the production cost per unit is low relative to other types of livestock and the return on investment is high, thus farmers need just a small amount of capital to start a poultry farm; and has a short production cycle. Ewung (2016) identifies one of the greatest problems confronting millions of Nigerians today as inadequate protein intake in quality. This inadequacy results in the problem of malnutrition with consequential effect on mental capability, which manifest in poor working productivity. Despite the growth recorded in the Nigerian poultry industry, demand for poultry products particularly, eggs still outweighs its supply. The situation is not getting any better as most of the farmers involved in the poultry egg production lack the technical knowledge, managerial ability and this has limited their ability to maximize profit which in turn translates into huge capital loss and hence discouragement and frustration (Audu, 2012). In a similar vein, Ekunwe *et al*. (2006), opined that many poultry farmers approach poultry production with mere hubby rather than the actual knowledge of the basic poultry production techniques that can help maximize production with the best inputs combination.

Farm production efficiency is the ability of a farm to produce a given level of output with the lowest number of resources. The efficient method of producing a product is the one that uses the least number of resources to get a given amount of output (Umar, H. S. *et al*., 2017). Efficient farms make better use of existing resources to produce maximum output or incur the lowest cost, thus, achieving the food security objective. An efficient farm has six features: zero waste, least cost, minimum risk, maximum output, best quality produce and maximum profit (Rahman, 2013). Scaling up output and sustainability of any enterprise depends largely on the productivity as well as profitability of the enterprise. This is possible when such enterprise is managed in an economically efficient manner. The current astronomical increase in the prices of production inputs make efficiency of resource combination and management (to maximize output) a necessary option in production decision (Umar, H. S. *et al*; 2022). Hence, this study is designed to estimate technical efficiency and profitability of layer-poultry production in North-central Nigeria.

METHODOLOGY

The Study Area

North-central zone is located between latitudes 6^0 30’ to 11^0 20’ North and longitudes 2^0 30’ to 10^0 30’ East. The zone occupies a total land area of 296,898 km^2 representing about 32% of the country’s land area. More than 77 % of the habitat of this region are engaged in one form of agricultural activity or the other. The zone experience both wet and dry seasons, with the wet season starting in March and end in October while the dry season ranges from November to March. The zone experiences an annual rainfall between 1000mm to 1500mm with an average of 187 to 220 rainy days and an average monthly temperature between 21^0 C and 37^0 C. the vegetation zone consists of the Forest Savannah, Southern Guinea Savannah and Northern Guinea Savannah (Ojo *et al*., 2014).

Sampling Procedure

A multistage sampling technique was used to select the respondents for the study. The first stage of sampling involved the purposive selection of three states namely; Plateau, Nasarawa and Niger. These states being contiguous to national headquarters, Abuja, which provides a ready market for poultry products, have more concentration of poultry businesses in the region.

Secondly, the list of poultry (layer) farmers in the metropolitan towns of Lafia and Keffi in Nasarawa State; Jos and Bukuru in Plateau State; and, Suleja and Minna in the Niger States were obtained from Agricultural Development Programme in each of the states. This list forms a sampling frame for the study. The next stage of sampling involved the random selection of 10% of the registered poultry (layer) farmers from each of the metropolitan towns in each state as follows: Nasarawa State (Lafia=30 and Keffi=22); Niger State (Minna= 35 and Suleja=25) and Plateau state (Jos= 20 and Bukuru=24). Hence, one hundred and fifty-six (156) layer farmers were selected for the study.

Method of Data Collection

Data for this study were mainly from primary sources. The data were collected using structured questionnaires complemented with a personal interview schedule. The data were collected from layer farmers on the following variables: inputs and output quantities and prices, demographic features of the farmers and challenges to poultry production

Method of Data Analysis

The stochastic frontier production model has been considered very helpful in measuring simultaneously production function and technical efficiency sources in production and the impact of measurements of errors, which are exogenous to production Battese *et al.* (2004). This model was first introduced by Aigner and Cain (1977); Meeusen and van den Broeck (1977), and further developed and used by several others, among which were Schmidt and Knox Lovell (1979); Bravo-Ureta et al. (2020); Kumbhakar and Tsionas (2021). The technical efficiency of a firm is the achievement of the maximum possible output for a given quantity of inputs given the physical production relationship (Bamiro and Shittu, 2009). Therefore, a farm is said to be inefficient if little is produced from too much input (Osinowo and Tolorunju, 2019) let's consider a farmer who uses farm inputs X_1, $X_2 \ldots\ldots\ldots X_n$, to produce output Y., to obtain a maximum possible output from the combination of different input combinations. The efficient transformation of these inputs to output is expressed by the production function *f (x).*

The stochastic frontier production function model can be mathematically expressed as

$$Y_i = f(X_i; \beta) \exp (\mu_i), \quad i= 1,2,3\ldots\ldots\ldots n \ldots\ldots (1)$$

The frontier production function $Y_i = f(X_i; \beta)$ is the measure of the maximum level of potential output for a given set of inputs X_i. The error term (μ_i) reflects the random deviations in output from the frontier. The composite error term has a component of V_i, representing the shocks and variations in production output due to inherent and uncontrollable factors beyond the producer's control (e.g., natural disasters, weather fluctuations). The error, V_i is symmetrical and assumed to be independent and identically distributed with a zero mean and constant variance $(0, \sigma v^2)$. The second error component is (U_i), a non-negative random variable that reflects technical inefficiency on the farmers' side is responsible for deviation in production below frontier production level. This error seems slightly different and independent of the V_i as it is non-negative with a non-zero mean, constant variance and is half normal $(0, \sigma^2 u)$ (Bravo-Ureta *et al*., 2020).

$$Y_i = f(X_i; \beta)\ f(X_i; \beta) \exp Vi\text{-}Ui= 1,2,3,..,n \ldots\ldots (2)$$

Y_i= production output for i^{th} farm

X_i= quantities of input vector for i^{th} farm

β= vectors of parameters that are unknown on the ith farm
V_i= cumulative error of random shocks
U_i= effects of inefficiency (non-negative).

The model above simultaneously estimates the technical efficiency of the individual respondent and the determinants of the technical efficiency of such respondent or farmer as in this case layer farmer. Empirically, Technical efficiency is measured by the decomposition of error deviations into a random component V_i and the inefficiency component U_i

The frontier output is given as

$Y^*_i = f(X_i; \beta) \exp Vi, \quad i= 1,2,3\ldots\ldots\ldots n$ .... *(3.*

Therefore, the technical efficiency of a specific farm is the ratio of observed farm output to the corresponding frontier potential output of that farm given the available Technology (Ojo, 2003).

$$TE = Y^*_i / Y_i = \frac{f (X_i; \beta) \exp (Vi-Ui)}{F (X_i; \beta) \exp Vi} \ldots\ldots \quad (4)$$

TE = f exp (U_i)

Model Specification

The Cobb-Douglas Stochastic Production function that assumes the poultry (layer) production technology employed by the farmers following Osinowo and Tolorunju (2019) and specified as follows:

$$\ln Y_i = \ln\beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + Vi - Ui \ldots\ldots (5)$$

Where;
ln = natural logarithm to base e,
Y_i= number of crates of the ith farm,
X_1 = initial stock (number of day-old chicks)
X_2 =medication in a litre
X_3 = feeds in Kg
X_4= labour in man-day
X_5=water in litre
X_6= fuel in a litre
β_i= vectors of the unknown parameters to be estimated
V_i = independent random errors which are assumed to be identically distributed with a zero mean and constant variance (0, σv^2)
U_i= variation arising from technical inefficiencies of the farmer.

The diverse level of farm output recorded by farmers could be attributed to the individual farmers' socioeconomic characteristics and farm attributes. To explain these output variations across the sample layers of farmers, these controllable factors (U_i) were hypothesized as determinants of technical efficiencies illustrated as follows:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} \ldots\ldots (6)$$

Ui = technical inefficiencies of the ith layer farmer
δ_0 = is the constant term
Z_1 = age of the ith farmer in years
Z_2 = poultry farming experience of the ith farmer in years
Z_3 = educational level of the ith farmer in years
Z_4 = household size of the ith farmer in number
$\delta_1 - \delta_4$ = coefficients of the maximum likelihood estimates

Gross Margin Analysis

Gross margin (GM) is the difference between the gross farm income (GI) and the total variable cost (TVC)
GM = GI – TVC
Where: GM = Gross Margin;
TR = Total Revenue;
TVC = Total Variable Cost
TFC = Total Fixed Cost farm Income

RESULTS AND DISCUSSION

Descriptive statistics of the variables used in estimation are presented in Table 1. The Table shows that the mean crate of eggs was 3,169 with the minimum number of crates of eggs as 330, while the maximum number of crates of eggs was 31, 040. However, the deviation of crate of eggs distribution from the mean as measured by standard deviation was large. Table 1 also shows that the mean initial-stock of birds was 603, maximum initial-stock was 8000 and the minimum stock was 50 birds with very wide standard deviation. The average litres of medication used to ensuring good health of the birds was 17, with a maximum of 75 litres and a minimum of 2 litres, while the standard deviation was 13. This shows low dispersion from the mean of litres of medication. The mean of feeds that was fed to poultry throughout production period was 9672kg (Table 1). The maximum feed was 16,000 Kg, while the minimum Kg of feed was 825, though there was high variability around the mean as measured by the Standard deviation.

The mean labour utilization as presented in Table 1 was 206 man-day with maximum of 480 man-day and 120 man-day as the minimum, while standard deviation was 150. Table 1 also shows that the mean of water utilization was 5709 litres, with a maximum of 9000 litres and a minimum of 500 litres. The amount of fuel used to generate power for the farm was also presented in Table 1: the mean of 16 litres, a maximum of 140 litres and a minimum of 1 litre, while standard deviation was 24. The wide variability of the variable distributions around their mean values as measured by standard deviation implied lack of knowledge of optimum resource management by most layer farmers.The mean age of the poultry farmers was 43 years which falls within the most active age of a working group in the country. The mean of formal education was 13 years. This implies that, on the average, the farmer poultry farmer had attained secondary education. The mean years of experience were 9. The experience they say is a teacher, farmers with more experience are usually expected to do better than those with less experience (Ezeh, *et al.*, 2012).

Costs and Return Analysis

The profitability of poultry (layers) production was determined and presented in Table 2. The result revealed that the Average Total Revenue (ATR) of production was ₦4,408,079 per 603 layers while the Average Total Variable Cost (ATVC) incurred was ₦3,161,053 per 603 birds. The average cost of feed was ₦3,066,024 per 603 birds. This constitutes about 97% of the total cost of production. This finding agrees with Odine *et al.* (2015) and Umar *et al.* (2022). According to Odine *etal.* (2015) the cost of feed for layers production was made up of 95 % of the total variable cost. Whereas the cost of fuel contributed the least (0.11 %) share of the total variable cost of the production; indicating that, fuel is not a limiting factor in the poultry production business in the study area. The result also revealed a gross margin (GM) of ₦1,247,026/ per 603 birds per production cycle indicating a profit of (one million four hundred and ninety-one thousand naira only. Return on investment (ROI) was revealed, to be positive with a value of (0.29) which implies that, for every ₦1.00 invested in poultry farming in the study area, 29kobo would be realized which a 29% return on investment.

Input-output Relationship

The Maximum Likelihood Estimation (MLE) of the Cobb-Douglas stochastic frontier production function for poultry (layer) farmers are shown in Table 3. The result revealed that coefficients of the variables (initial stocks, medication, and labour) carried a positive sign and were significant at 1 and 5% levels of probability. This is confirmed by (Umar, H.S. *et al*; 2022). While the coefficient of fuel variable carried a negative sign and was significant at a 1 % probability level respectively. The positive sign and significance of the coefficients of initial stock, medication, and labour variables imply that a percentage increase in these variables would increase the number of a crate of eggs produced respectively. Though the coefficient of fuel is significant but carried negative sign, indicating an inverse relationship with the output, any increment in the quantity of fuel will lead to a decrease in the number of eggs produced. Since the elasticity is greater than one, it suggests that the poultry (egg) producers are operating at stage one of the total product (TP) curve. At this stage, the marginal product of poultry farmers is greater than the average product. Hence, increase in the use of inputs will lead to more than proportional increase in output.

Technical Efficiency

The Technical Efficiency of Poultry farms is presented in Table 4. The result ranges between 0.10 and 0.94 with a mean value of 0.72. This result implies that the technical efficiency of poultry farmers in the study area could be increased by 28% given the current level of technology if the available resources are efficiently utilized. This report agrees with the report of Olasunkanmi *et al* (2013) who realized the mean efficiency of 72% in their report. But disagrees with Ahiale *et al* (2019) whose technical efficiency was found to be 87%.

Determinants of Technical Inefficiency in Poultry (Egg) Production

The factors that influence the technical inefficiency of layer farmers in North Central Nigeria were estimated from the Cobb-Douglas stochastic frontier production function and the results are presented in Table 5. The significant coefficients of variance (σ^2) and Gamma γ confirmed the influence of the inefficiency effect in the model. The significant of two parameters were reported by Alabi, and Aruna (2005). Table 5 shows that farmers' age and level of education have significant effects on the level of technical inefficiency with their coefficients of -1.926, and -1.942, which were significant at 5% probability level respectively. The negative signs indicated inverse relationship with technical efficiency, which imply that an increase in these variables would decrease the inefficiency level of the farmers. The results agree with that of Ahiale *et al.* (2019), who reported that age and level of education have relationship with the level of technical inefficiency.

Constraints to Poultry Production

The results in Table 6 shows that the problem of high cost of feed was ranked 1st in order of severity of challenges confronting the poultry farmers in the study area. The implication is that high cost of feed could constrain the realization of profit maximization motive. It is however not surprising as seen in Table 1, where the cost of feed contributed 96.99 % to the total variable cost of production. This finding is in agreement with the finding of Omolayo (2018) who identify the high cost of feed as one of the major constraints to poultry business in Lagos State Nigeria. Table 6 also revealed that the incidence of diseases ranked 2nd in the order of severity as a large number of farmers (33 %) in the study area identified this problem as major challenge confronting their business activity. The problem of diseases if not properly managed, have the propensity to wipe out the whole of the poultry birds thereby sending the farmer out of business. Furthermore, high mortality rate and bad weather were among the problems confronting poultry (egg) producers in the study area. The problems were ranked 3rd and 4th in order of severity. However, problem of bad weather was the least of all the problems confronting the poultry farmers in the study area, where few (14%) of the farmers encountered this problem in their poultry farming activities. The implication is that bad weather harms the feeding habit of poultry which consequently hurts the quantity and quality of the egg produced.

Table 1: Descriptive statistics of the variables used in estimation

Variables	Mean	maximum	Minimum	Std. Deviation
Crates of eggs (Number)	3169	31040	330	3488
Initial Stock (Number)	603	8000	50	1077
Medication (Litre)	17	75	2	13
Feed (Kg)	9672	16000	825	2101
Labor (Man-day)	206	480	120	105
Water (Litre)	5709	9000	500	8244
Fuel (Litre)	16	140	1	24
Age (Year)	43	68	16	9
Farming Experience (Year)	9	25	1	7
Educational (Year)	13	16	2	4
House hold Size (Number)	7	19	1	4

Table 2: Cost and return per 603 birds per production cycle

Variable	Av. Quantity	Average Unit Price (₦)	Av. Cost/Revenue (₦)	% of the total cost
A) Output				
Number of Crates	3,169	1391	4,408,079	
Total Revenue = ₦ 4,408,079				
B) Variable Inputs				
Initial Stock (No)	603	419	252,657	7.99
Feed (Kg)	9672	317	3,066,024	96.99
Medication (litre)	17	630	10,710	0.34
Labour (man-day)	206	332	68,392	2.16
Water (litre)	5709	2	11,418	0.36
Fuel (Litre)	16	225	3,600	0.11
Total Variable Cost = ₦3,161,053				
Gross Margin = Total Revenue - Total Variable Cost = ₦1,247,026				

Table 3: Maximum likelihood estimation (MLE) of the layers production function

Variable	Parameter	Coefficients	Standard error	t-ratio
constant	β_0	2.997	0.492	6.089***
Initial stock (number)	β_1	0.654	0.071	9.248***
Medication (litre)	β_2	0.104	0.047	2.201**
Feeds (Kg)	β_3	0.068	0.041	1.361
Labour (man-day)	β_4	0.246	0.118	2.091**
Water (Litre)	β_5	0.008	0.048	0.158
Fuel (litre)	β_6	-0.159	0.025	-6.475***

Note: *** = significant at 1% probability level; **= significant at 5% probability level

Table 4: Frequency distribution of technical efficiency among poultry (layer) farmers

TE Range	Frequency	Percentage
≤ 0.20	1	0.64
0.21 - 0. 40	11	7.05
0.41 - 0. 60	18	11.54
0.61 - 0. 80	64	41.03
0.81 - 1.00	62	39.74
Total	156	100

Mean Technical Efficiency 72 %
Minimum Technical Efficiency 10 %
Maximum Technical Efficiency 94 %

Table 5: Inefficiency Factors

Variable	Parameter	Coefficients	Standard error	t-ratio
constant	δ_0	-0.002	9.411	-1.916*
Age	δ_1	-1.926	0.761	-2.530**
Farming Experience	δ_2	2.259	1.792	1.260
Level of Education	δ_3	-1.942	0.885	-2.195**
Household Size	δ_4	-2.244	1.633	-1.374
Sigma-squared σ^2		1.693	0.675	2.508**
Gamma γ		0.958	0.034	28.390***

Log likelihood function = -104.890
*, **, *** significant at 10%, 5% and 1% levels respectively

Table 6: Constraints to poultry production

Constraints	Frequency	Percentage	Ranking
High cost of feed	81	52	1st
Incidence of diseases	51	33	2nd
High mortality rate	46	29	3rd
Bad weather	22	14	4th

Note: Multiple responses allowed

CONCLUSION AND RECOMMENDATIONS

This study was conducted to analyze the profitability and technical efficiency of poultry (layers) Production in the North-central Nigeria. The findings indicated that poultry (layer) production is a profitable venture in the study area. This is evident in the positive Gross Margin of ₦1,247,026 per 603 birds per production cycle. The poultry enterprise was characterized by return to scale, though the technical efficiency of the farmers could be increased by 28% given the current level of technology. The farmers' age and level of education have significant influence on the inefficiency effect of the farmers. High cost of feed, incidence of disease and high mortality rate were major challenges confronting poultry farmers in the study area.
The study therefore made recommendations as follows: all stakeholders in the poultry value chain businesses should come together to deliberate how best to curtail the spirally rise in price of poultry feeds in the country. Addressing this problem has potential of increasing significantly the fortunes in the poultry enterprise. By extension, the industry will becomes more attractive to the unemployed youth in the country. Poultry farmers should be encouraged to form a cooperative in order to enjoy the economies of scale in the purchase of sensitive input like feed. Both private and public extension agents should be encouraged to visit the poultry farmers regularly to proffer appropriate guidance in improving the efficiency of production.

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ASSESSMENT OF AGRO-PESTICIDES USAGE IN MAKURDI AND LAFIA AREAS OF BENUE AND NASARAWA STATES, NIGERIA

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ABSTRACT

The rate of pesticide-related death is high in developing countries like Nigeria despite regulations on high-risk forms of pesticides. This study was carried out to assess pesticides availability, types and uses in Lafia and Makurdi of Nasarawa and Benue States. Five major Agro-chemical distributors were randomly selected in each of the cities. Under each major Agro-chemical distributor, five distributors were identified and selected. Fifteen (15) stakeholders were identified under each of the minor distributors. Thus, each state had a representative of 75 making a total of 150 respondents for the study. Structured questionnaire was employed for data collection. The data collected were subjected to descriptive statistics technique (frequency and percentages). The results of the study revealed that majority (65.96%) of the pesticides were imported from China. The major unit of measurement for pesticides was litres (83.7%). Emulsifiable concentrates constituted the highest (81.2 and 75.2%) form of formulation in both Makurdi and Lafia, respectively. Also, organophosphate (51.5 and 53.9%) was the major class of insecticides while glyphosate (49.6 and 36.8%) was the major class of herbicides in use in the two major cities, respectively. In both cities, majority (96.6 and 95.5%) of the pesticides were applied by spraying; while 78.4 and 73.4% of the pesticides were applied as contact pesticides. The most effective ingredient in use among the insecticides was dichlorvos while that of herbicides was glyphosate. The study also revealed that more herbicide was sold and used in Makurdi and Lafia representing 52.1% and 50.9%, respectively. Insecticides and herbicides were the most often used pesticides by farmers in both cities, and they were widely available and marketed. The study recommended an aggressive promotion of Integrated Pest Management Scheme and increasing public awareness and knowledge of banned pesticides.

Key words: Agro-chemical, pesticides, herbicide, insecticides, active ingredients.

INTRODUCTION

The term pesticides are used broadly to include: all chemical products such as carbamate, organ chlorines, organophosphates, and phyrenthrins, or biological agent (such as virus, bacterium or fungus) that deters, control or kill of pests, diseases and weeds in crop, including vectors of human or animal disease, unwanted species of plants or animals. (Wilbert, 2019). Pesticides are also any substances or mixture which are used to repel or attract pests in order to minimize their detrimental effects or used to sterilize, stupefy or mitigate any insects causing harm during or otherwise interfering with the production, processing, storage of agricultural commodities (Ishwar and Ningombam, 2017). Pesticides are also used for other purposes, such as the improvement and maintenance of non-agricultural areas like public urban green areas and sport fields (CCS, 2013). In the process of agricultural development, pesticides became a vital tool for plant protection and enhancing crop yield. Approximately, 45% of the annual food production is lost due to pest infestation; therefore, effective pest management by using wide range of pesticides is required to confront pests and increase crop production (Onder *et al*., 2011). Pesticides with less hazard to health is very important in production of safe food (Delcour *et al.*, 2015).

The absence of pests impacting agricultural productivity is an evident advantage of insecticides. The increased output allows for an increase in income, more and cheaper food the consumer. The need for manual labor to manually remove pests such as weeds is decreased, allowing for financial savings. Another important benefit of using pesticides is the prevention of diseases from insects and rodents. (Cooper and Dobson, 2007). All chemical pesticides must be used strategically in the farming systems and new tools or techniques with greater reliability than those already existing are needed to predict the potential hazards of pesticides and thus, contributing to reduction of the adverse effects on human health and the environment (Christos and Ilias, 2011). Reforming agricultural practices aligned to fulfill these criteria is a step toward the sustainability of the agricultural sector in contrast to precision agriculture (Watcharaanantapong *et al*., 2014). The earliest recorded instance of pest control was the use of Sulphur compounds by the ancient Sumerians to kill insects. The ancient Greeks were reported to have used fire to chase away locusts to the sea (Unsworth, 2010). The earliest recorded use of pesticides to control pests was the use of “Bordeaux mixture” which was a combination of copper sulphate and lime, to control downy mildew, a serious fungal disease of grapes (Coll and Wajnberg, 2017). Modern era of chemical pest control commenced during World War II when dichloro-diphenyl tetrachloroethane (DDT) was developed as the first modern synthetic insecticides in the 1940s and played a major role in the health and welfare of soldiers returning from war zone, and the DDT was used to control body lice and mosquitoes which transmitted major disease as malaria (EPA, 2012).

Pesticides are classified based on chemical composition, target to control, mode of use (formulation), mode of action (either as systemic, non-systemic, fumigant, pre or post treatment) and toxicity levels. DDT, BHC, Aldrin and Endosulphan and their allies are pesticides belonging to the organochlorines. Pesticides in the group of organophosphates are malathion, parathion and fenitrothion; while carbamates are carbofuran, propoxur and aldicarb (Lushchak *et al*., 2018). Pesticides are generally formulated to be specific in their target species. Hence, we have Insecticide - Insects, Fungicide - Fungi, Herbicides – Weeds, Antimicrobials – Bacteria, Acaricides - Mites and spiders, Rodenticides - Mice and other rodents, Nematicides – Nematodes, Repellants - Insects, birds, mammals, Plant Growth Regulators for insects and plants, Wood

Preservatives - against fungi, bacteria, and insects (NWSEPA, 2013). Currently, around two million tons of pesticides are used per year on a global basis, most of which are herbicides (50%), followed by insecticides (30%), fungicides (18%) and other types such as rodenticides and nematicides (2%) (Sharma *et al*., 2019). Even as the European Union sees regulatory approvals of chemical substances used in pesticides decline, demand is increasing in many developing countries, which together account for a quarter of global pesticide usage (UNICEF, 2018).

Modern chemical pesticides are sophisticated compounds which are carefully researched to ensure that they are effective against target organisms, safe to the environment and can be used without undue hazards to the operators or consumers. Pesticide use has raised serious concerns not only of potential effects on human health, but also about impacts on wildlife and sensitive ecosystems (Power, 2010). Chemical pesticides are now a necessary component of contemporary life. It is reasoned that without pesticides some crops might have been entirely destroyed. It has been estimated that globally nearly $38 billion are spent on pesticides each year (Pan-Germany, 2012). Despite the importance of pesticides use in agriculture, food security, trade and poverty reduction, agricultural production, storage and marketing face many setbacks that need attention from researcher. Increased quantity and frequency of pesticide applications over the years and reported cases of reactions to some pesticides have posed a major challenge to the targeted pests causing them to either disperse to new environment and/or adapt to the novel conditions (Cothran *et al.*, 2013).

The first reported case of hazardous use of chemical pesticide was the classic report made against dichloro-diphenyl tetrachloroethane (DDT) in the book Silent Spring by Rachel Carson was published over 50 years ago and revealed the hazards of DDT to human health, wildlife and environment (Carson, 1962). Thereafter, other countries discontinued the use of DDT, as well (Bernands *et al.,* 2015). Observations showed that DDT has the ability to induce the epigenetic transgenerational inheritance of obesity, kidney, testis and ovary disease (Skinner *et al*., 2013). DDT is known to be very persistent in the environment, will accumulate in fatty tissues, and can travel long distances in the upper atmosphere with the escalation of more toxic material. Additional pesticides (persistent organic pollutants {POP} or highly hazardous pesticides {HHPs}) have been identified and the group includes aldrin, endrin, chlordane, DDT, dieldrin, heptachlor, Mirex, toxaphene, hexachlorobenzene (HCB), and polychlorinated biphenyls (PCBs) and two contaminants, polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (Ashraf *et al.*, 2013).

However, despite environmental and health hazards related to the use of DDT, its use to fight malaria is being propagated by the World Health Organization (WHO) and at the same time promoting the use of drug treatment and insecticide treated bed nets for malaria control (Rehwagen, 2006; WHO, 2011). Besides acute risk of occupational poisoning, use of acutely toxic pesticides for self-harm purposes made WHO therefore recommends that acutely toxic products are made less accessible (WHO 2014). On the basis of this the National Agency for Food and Drug Administration and Control (NAFDAC) has reviewed its regulations, guidelines and strengthen collaboration with government agencies and stakeholders to ensure effective regulations, and such collaborative effort has been recorded in agrochemicals regulation and other areas. Accordingly, it has been reported that NAFDAC has reviewed the safety of all registered agrochemicals in Nigeria in consultation with relevant stakeholders, and had initiated a four year' phase-out plan for obsolete and some hazardous agrochemicals; such phase-out plan is currently running for Paraquat, which will be phase-out in the country by 2024 and Atrazine by 2025; while 100 ml pack size of Dichlorvos (DDVP) is already banned due to inappropriate use (NAFDAC, 2022).

It has been advocated that a prudent and responsible use of pesticides is the paramount caution to be followed while dealing with pesticides (VMAP, 2022). Although, farmers' knowledge and awareness of pesticide risk plays an important role in determining the use of Personal Protection Equipment (PPE) while their level of education plays an important role in increasing the knowledge of pesticide risks (Jensen *et al.*, 2011; Ojo, 2016). Moreover, some banned pesticides may be available in the form of counterfeit/adulterated and/or contraband pesticides either in the developing or developed countries (Bayoumi, 2021). Ojo (2016) noted the use of cheaper but deadliest forms of pesticides as one of the primary factors responsible for the well-cited data that 99% of pesticide-related deaths occur in poorer countries such as Nigeria and other developing countries. The objectives of this study therefore, are to assess the types and available pesticides in use in the study areas and to determine the types of banned pesticides available in both Lafia and Makurdi of Nasarawa and Benue States, respectively.

MATERIALS AND METHOD.

Description of the Study Areas

The study was conducted in Lafia and Makurdi in Nasarawa and Benue States. Lafia is located between Latitude 08^0. 33^iN and representative of 75 stakeholders (agro-dealers, ADP staff, and farmers), totaling 150 Longitude 08^0. 32^iE at altitude of 160 m above sea level (Jayeoba, 2013). Lafia has a population of roughly 361,000 people. (Lafia, Nigeria Metro Area Population, 2022). The area is bordered by Obi Local Government Area to the South, Nasarawa-Eggon to the North, Doma Local Government Area to the West and Quan Pan Local Government Area of Plateau State to the East. The main ethnic and language groups in the area are the Lafia Beriberi, Gwandara, Eggon, Alago and Migili. While Makurdi is located on Latitude 07^0. 73^iN and Longitude 8^0. 53^iE. The population of the area is about 438,000 (NPC, 2022). The area shares boundary with Guma Local Government to the North-East, Gwer Local Government to the South, Gwer-West to the West and Doma Local Government Area of Nasarawa State to the North-West. Makurdi is divided into two major blocks by river Benue hence the North and South Banks. The main ethnic and language group in the area is Tiv.

Research Design and Data Collection

Structured Questionnaire method was used to obtain information from, Agro-Chemical Companies, Agricultural Development Programme (ADPs), Agro-Chemical dealers and farmers. In each location, information was obtained physically on all labelled pesticide containers and oral information was obtained from the respondents. The questionnaire was made up of two sections, information on pesticides and responses of the farmers on the usage. The five major Agro-Chemical distributors were chosen as a representative of Agro-Chemical companies as they serve as the first point of distribution to other dealers in the states. Under each major Agro-Chemical distributor, five distributors were identified and selected. Fifteen (15) stakeholders were thereafter, identified under each of these minor distributors. Thus, each state had a respondents for the survey work (Table 1). Each respondent selected was physically visited for a face-to-face interview to obtain and ascertain the information on types and availability of safe pesticides and banned pesticides (Tables 2 and 3) in use in the study area.

Method of Data Analysis

Descriptive statistical techniques (frequency and percentage) were used to analyze the data. All statistical analyses were run on Statistical Package for Social Sciences (SPSS) version 16.

RESULTS

Sources and Packaging of Pesticides in use at Makurdi and Lafia

Country of origin of pesticides available in the study area is presented in Table 4. A total number of 467 and 440 pesticides were identified as being in use in the two study areas. The result revealed that, shows majority (65.9 and 76.1%) of the pesticides in the study area were from China while the least (0.4 and 0.5%) were from Nigeria and Spain, respectively. Table 5 shows that majority (83.7 and 70%) of the pesticides were packaged in litres while 13.7 and 22% are packaged in ml, with the least (2.6% and 7%) in grams or kilogram at the respective major cities.

Active ingredient of Insecticides and Herbicides; Types of Formulation and Mode of Application of Pesticides Available at the Two Cities Surveyed

Table 6 reveals that majority (52.69 and 54.96%; 57.52 and 47.00%; 19.40 and 16.36%; 39.29 and 43.24%) of the active ingredients were Dichlorvos, Paraquat, Carboxin, and Bromadiolone, for insecticides, herbicides, fungicides and rodenticides, respectively. Table 7 shows that majority (80.30 and 74.30%) of the pesticides were formulated as emulsifiable concentrate while the least (0.21 and 0.24%) were fumigants. The result also reveals that majority (96.37 and 95.22%) of the pesticides were applied by spraying while fumigation and were the least (0.21% in the both cities). Table 9 revealed that contact pesticides were the major (78.4 and 73.4%) mode of action of pesticides while 21.6 and 26.6% were through systemic.

Availability of pesticides used presently by the farmers in the study areas and Target pest

Table 10 showed that the majority of the insecticides (86.67 and 93.33%) and herbicides (100 and 100%) used by farmers are readily available in Makurdi and Lafia cities. Majority (66.67% and 60.00%) of the respondents opined that fungicides are occasionally available in Lafia and readily available in Makurdi. However, majority (80 and 84%) of the respondents indicated that rodenticides are occasionally available in Makurdi and Lafia in both cities. Opinions about marketability of pesticides in both cities are presented in Table 11. The results revealed that insecticides (73.33 and 82.66%) and herbicides (80 and 100%) are highly marketable in Makurdi (73.33 and 86.00%) and Lafia.

Table 2: Lists of Agrochemicals Banned in the United States of America and United Kingdom

Common name	Pesticide Type	Active ingredient	WHO Classification of Toxicity
2,4,5-T	Herbicide	2,4,5-Trichlorophenoxyacetic acid	Class I: Highly Toxic
2,4,5-TCP	Fungicide and Herbicide	2,4,5-Trichlorophenol	Class I: Highly Toxic
Furfural	Fungicides and Nematicides	2,3,4,5-Bistetrahydro- 2-furaldehyde	Class II: Toxic
Aldrin	Insecticide	Organochlorine	Class II: Toxic
BHC	Insecticide	Benzene hexachloride	Class II: Toxic
Binapacryl	Fungicide and Miticide	2-sec-butyl-4,6-dinitrophenyl 3-methylbut-2-enoate	Class IV: Slightly Toxic
Cadmiun	General pesticide	Cadmiun chloride	Class I: Highly Toxic
Chemtox and Industriox	Fumigant	Carbon tetrachloride	Class I: Highly Toxic
Chloranil	Fungicide	Quinone - 1,4-benzoquinone	Class II: Toxic
Chlordecone (kepone)	Fungicide and Insecticide	Organochlorine	Class II: Toxic
Chlordimeform	Anti-feedant, Insecticide and Acaricide	4-Chloro-o-toluidine	Class II: Toxic
Chlorobenzilate	Miticide	Lindane – Organochlorine	Class II: Toxic
DBCP	Soil Fumigant	1,2-Dibromo-3-chloropropane	Class I: Highly Toxic
Dieldrin	Insecticide	Organochlorine	Class II: Toxic
Endrin	Insecticide	Organochlorine	Class II: Toxic
Dinoseb	Herbicide	6-sec-butyl-2,4-dinitrophenol	Class I: Highly Toxic
Ethyl hexyleneglycol	Softener of non-aqueous pesticides	*Hexylene glycol*	Class I: Highly Toxic
Ethylene dibromide (EDB)	Fumigant	1,2-Dibromoethane	Class I: Highly Toxic
Ethylene dichloride (EDC)	For the production of vinyl chloride monomer (VCM) in pesticides	1,2-*Dichloroethane*	Class IV - Slightly toxic
Heptachlor	Insecticide	Organochlorine	Class II: Toxic
Leptophos	Insecticide	Organophosphate-Phenylsaligenin phosphate	Class I: Highly Toxic
Mirex	Insecticide	Organochlorine	Class II: Toxic
Nitrofen (TOK)	Herbicide	2,4-dichloro-4′-nitrodiphenyl ether	Class I: Highly Toxic
Octamethylpyrophosphoramide (OMPA)	Insecticide	Organophosphate	Class I: Highly Toxic
Polychlorinated biphenyls (PCB)	Coolant in the production of Pesticides	Polychlorinated biphenyls	Class IV - Slightly toxic
Safrole	Used to give fragrance to pesticides and Antifeedant	Piperonal via isosafrole	Class II: Toxic
Silvex	Defoliant	Fenoprop and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid)	Class II: Toxic
Thallium sulfate	Rodenticide and Insecticide	Thallous acetate and Thallic *chloride*	Class I: Highly Toxic
Toxaphene	Insecticide	Heptachlorobornane	Class I: Highly Toxic
Strobane	Insecticide	Terpene polychlorinates	Class I: Highly Toxic
Paraquat, Diquat	Herbicide	N, N′-dimethyl-4,4′-bipyridinium dichloride	Class I: Highly Toxic
Imidacloprid	Insecticide	Neonicotinoids	Class I: Highly Toxic
Cyhalothrin	Insecticide	Gamma-cyhalothrin and lambda-cyhalothrin (Pyrethroids)	Class II: Toxic
Telone, 1,3-D	Insecticide	1,3-dichloropropene (Organochloride)	Class I: Highly Toxic
Desmedipham,	Herbicide	Ethyl 3-phenylcarbamoyloxycarbanilate	Class I: Highly Toxic
Propanil	Herbicide	Propanoic acid with the amino group of 3,4-dichloroaniline	Class I: Highly Toxic
Chlorpropham	Herbicide	3-chlorophenylcarbamic acid (Carbamate)	Class I: Highly Toxic
Dichlobenil	Herbicide	2,6-Dichlorobenzonitrile (DCBN or Dichlobenil)	Class I: Highly Toxic
Iprodione	Fungicide	3-(3,5-dichlorophenyl)-N-(1-methylethyl)-2, 4-dioxo-1-imidazolidinecarboxamide	Class II: Toxic

Source: Survey 2021 and adapted data from Buffington and McDonald (2003); UNPIC (2003) and Cavallito (2020)

Table 1: Sources of information about the pesticide used at Makurdi and Lafia

Sources	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
ADPs	40	53.33	35	46.67
Agro-dealers	20	26.67	21	28.00
Farmers	10	13.33	15	20.00
Agric show	5	6.67	4	5.33
Total	75	100	75	100

Table 3: List of pesticides banned in Nigeria

PESTICIDES	CATEGORY
Aldrin	Insecticide
Binapacryl	Fungicide
Captafol	Fungicide
Chlordane	Insecticide
Chlordimeform	Insecticide
DDT	Insecticide
Dieldrin	Insecticide
Dinoseb and Dinoseb Salts	Herbicide
Heptachlor	Herbicide
Lindane	Insecticide
Ethylene Dichloride	Fumigants
Parathion	Insecticide
Methyiphrathion	Insecticide
Monocroptophos	Insecticide
Methamidophos	Insecticide
Chlorobenzilate	Insecticide
Toxaphene	Insecticide
Pentachlorophenol	Herbicide, Insecticide
Ethylene Oxide	Fumigant, Disinfectant
HCF (Mixed Isomers)/BHC	Insecticide
EDB (1,2-Dibromoethene	Fumigant
2,4,5 Trichlorophenoxy Acetic Acid	Herbicide
Endrin	Insecticide
Mirex	Insecticide
Ethylene Dibromide	Fumigant
Hexachlorobenzene	Fungicide
Phosphamidon	Insecticide
Endosulphan	Acaricide/Insecticide
Delta HCH	Insecticide
Flouracetamide	Rodenticide

Source: VMAP, (2022)

Table 4: Country of Origin of Pesticides in use at Makurdi and Lafia

	Makurdi		Lafia	
Country of Origin	Frequency	Percentage	Frequency	Percentage
China	308	65.9	335	76.1
Japan	15	3.2	9	2
India	92	19.7	55	12.5
Belgium	20	4.3	5	1.1
Venezuela	6	1.3	3	0.7
Switzerland	19	4.1	25	5.7
France	3	0.6	2	0.5
Nigeria	2	0.4	2	0.5
Spain	2	0.4	2	0.5
Total	467	100	440	100

Table 5: Packaging of Pesticides in Use at Makurdi and Lafia

Packaging	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
ml	64	13.71	97	22.05
kg	12	2.57	31	7.04
G	3	0.64	3	0.68
l litre	388	83.08	309	70.23
Total	467	100	440	100

Table 7: Formulation Types Available at the two major cities surveyed

Formulation available*	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
EC	375	80.30	327	74.32
WP	26	5.57	21	4.77
SC	60	12.85	84	19.09
FW	2	0.43	4	0.91
Fumigant	1	0.21	1	0.23
Bait	3	0.64	3	0.68
Total	467	100	440	100

*EC= Emulsifiable Concentrates, WP= Wettable Powders, SC= Soluble Concentrates, FW= Flowable

Table 6: Pesticide Active ingredients in use Identified within the two cities

Active ingredient	Makurdi		Lafia	
Insecticides	Frequency	Percentage	Frequency	Percentage
Dichlorvos	98	52.69	72	54.96
Lambda-cyhalothrin	14	7.53	9	6.87
Cypermethrin	33	17.74	24	18.33
Deltamethrin	15	8.06	8	6.11
Imidacloprid + betacyfluthrin + cyclohexane	23	12.36	15	11.45
Carbaryl	1	0.54	1	0.76
Carbofuran	1	0.54	1	0.76
Aluminum Phosphide	1	0.54	1	0.76
Total	186	100	131	100
Herbicides				
Paraquat, Paraquat + Atrazine, Paraquat + Dinitroaniline	107	57.52	102	47.00
Glyphosate	52	27.96	69	31.80
2-choro-N-(2,6-diethylphenyl) acetamide	17	9.14	21	9.68
Metolachlor + Atrazine	10	5.38	25	11.52
Total	186	100	217	100
Fungicides				
Mancozeb and Metiram	7	10.45	7	12.73
Dimethormorph + Pyraclostrobin	4	5.97	0	0.00
Zinc with the ethylene bis(dithiocarbamate) anionic ligand.	5	7.46	4	7.27
Thiram	2	2.99	6	10.91
Phthalimide	6	8.96	7	12.73
Benzimidazole	13	19.40	9	16.36
Azoxystrobin	9	13.43	7	12.73
Chlorothanolil	2	2.99	0	0.00
Carboxin, Furathocarb and Metalaxyl	19	28.35	15	27.27
Total	67	100	55	100
Rodenticides				
Zinc Phosphide	8	28.57	16	43.24
Chlorophacinone	9	32.14	12	32.44
Fluorine	11	39.29	9	24.32
Total	28	100	37	100
Insecticides	186	39.83	131	29.77
Herbicides	186	39.83	217	49.32
Fungicides	67	14.34	55	12.50
Rodenticides	28	6.00	37	8.41
Total	467	100	440	100

Table 8: Mode of Application of Pesticides at the surveyed areas

Mode of application of pesticides	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
Spraying	450	96.37	419	95.22
Dusting	15	3.21	19	4.32
Fumigation	1	0.21	1	0.23
Baiting	1	0.21	1	0.23
Total	467	100	440	100

Table 9: Mode of Action of Pesticides in Use at the Surveyed Areas

Mode of application of pesticides	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
Systemic	99	21.20	115	26.13
Contact	366	78.38	323	73.41
Fumigant	1	0.21	1	0.23
Baiting	1	0.21	1	0.23
Total	467	100	440	100

Table 10: Availability of pesticides used by the farmers in the study areas

Availability	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
		Insecticides		
Readily available	65	86.67	70	93.33
Occasionally available	10	13.33	5	6.67
Not available	0	0.00	0.00	0.00
Total	75	100	75	100
		Herbicides		
Readily available	75	100	75	100
Occasionally available	0.00	0.00	0.00	0.00
Not available	0.00	0.00	0.00	0.00
Total	75	100	75	100
		Fungicides		
Readily available	25	33.33	45	60.00
Occasionally available	50	66.67	30	40.00
Not available	0.00	0.00	0.00	0.00
Total	75	100	75	100
		Rodenticides		
Readily available	15	20.00	12	16.00
Occasionally available	60	80.00	63	84.00
Not available	0.00	0.00	0.00	0.00
Total	75	100	75	100

Table 11: Marketability of pesticides used by the farmers within the study areas

Marketability	Makurdi		Lafia	
	Frequency	Percentage	Frequency	Percentage
		Insecticides		
Highly Marketable	55	73.33	62	82.66
Readily Marketable	15	20.00	8	10.67
Occasionally Marketable	5	6.67	5	6.67
Not Marketable	0	0.00	0.00	0.00
Total	75	100	75	100
		Herbicides		
Highly Marketable	60	80.00	75	100
Readily Marketable	10	13.33	0.00	0.00
Occasionally Marketable	5	6.67	0.00	0.00
Not Marketable	0.00	0.00	0.00	0.00
Total	75	100	75	100
		Fungicides		
Highly Marketable	15	20.00	19	25.33
Readily Marketable	35	46.67	14	18.67
Occasionally Marketable	25	33.33	42	56.00
Not Marketable	0.00	0.00	0.00	0.00
Total	75	100	75	100
		Rodenticides		
Highly Marketable	15	20.00	35	46.66
Readily Marketable	14	18.67	23	30.67
Occasionally Marketable	46	61.33	17	22.67
Not Marketable	0.00	0.00	0.00	0.00
Total	75	100	75	100

DISCUSSION

The results from this study shows that some banned pesticides are such as paraquat and diquat (herbicides), imidacloprid, parathion, endosulphan and lambda-cyhalothrin (insecticides) are sold and used within the study area (Tables 2, 3 and 6). Glyphosate which is commonly used among the farmers has also been reportedly banned in India due to its degradation effect on the environment (Gandhi *et al*., 2021). However, Fernandez-Cornejo *et al*. (2014) reported that Glyphosate has been found to have low bio-accumulation in the environment as the chemical constituents are easily degraded microbes hence; it is less toxic and persistent than traditional herbicides. The results observed in this study is in consonance with the reports of USEPA (2018) that most of the pesticides banned in the USA, UK and India are sold and used in the developing countries.

The results of this study have shown that most of the pesticides used for agriculture production are of foreign origin mostly China while Nigeria and Spain have the least as seen in Table 4. According to Sharma *et al*. (2019) majority of pesticides used in the Third World are produced in China, United States of America and India and these countries and others consume more pesticides than most of the developing countries. This is in agreement with the report of this study as shown in Table 4. The pesticides are packaged mostly in liters, kilograms and mills with the greatest percentage being in liters and the least in kilogram as shown in Table 5. Due to the nature of farm sizes in Nigeria, farmers purchase little quantities of pesticides at a time. This assertion was collaborated by the report of Rapsomanikis (2015) who indicated that famers in Africa generally own smallholder *farms* which can be relatively larger, but only marginally. Hence, the purchase of pesticides is relative to the size of the farms to apply the pesticides. As shown in Table 5, much of the pesticides being sold were in 1 litre packs than in drums. This indicated that farmers can easily purchase few quantities of pesticides that can easily be used on the farms. The way and manner in which the pesticides are presented to farmers influence the efficacy of the pesticides on pests. Most of the farmers that use pesticides for storage require small quantities. Pesticides packaged in the form that needs water for mixing, may require large quantity of water to use and if these chemicals are not exhausted, disposing it off will cause pollution.

The study revealed that weeds and insects were the major target pests as seen in Table 6. The study showed that herbicides, insecticides and fungicides (Table 6) were predominantly used than any other types of pesticides. Table 6 also revealed that DDVP, Cypermethrin and Imidacloprid form the majority of the active ingredient of the insecticide sampled in the study area while pendimethalin forms the least. Paraquat and its allies were predominantly used than any other form of herbicides. According to SINDAG (2012) higher quantities of herbicides (56.1%), insecticides (26%) and fungicides (15.4%) are used worldwide than any other classes of pesticides. The preponderance of using more herbicides could be as a result of the ecology of the area that support the growth of vegetation compared to the arid ecological zones. More insecticides were also used because according to Hendrichs *et al*. (2007) more insect pests have evolved over the millennia to compete effectively with humans since the introduction of agriculture due to adaptation. It could also be deduced from the Table 6 that the use of fungicides in the study area could be due to the favourable environmental condition vis-a-viz humidity and temperature, which would have supported the incidences of fungal outbreak leading to more application of fungicides (Hernandez and Martinez, 2018).

As indicated in Table 7, most of the pesticide formulations available in the study areas were emulsifiable concentrates (EC) with flowable being the least. Pesticides can be presented for use in form of emulsifiable concentrates, wettable powder, flowable and granules (Dipak and Aloke, 2019). EC is the most commonly formulation of pesticides in the areas where the study was carried out, this is because the farmers enjoy abundant rainfall during the season and hence, there is ample chance to apply the pesticides by spraying (Table 8) using Knapsack sprayers. It has been reported by Knowles (2009) that the mode of pesticide application in areas where there is abundant water is by spraying water as carrier of pesticides compared to arid regions where there are less rainfall for use. Other methods of application included dusting and fumigation. Problems associated with spraying method include spray drift, volatilization and blocking of spray nozzles if sediments are present as reported by (Zhang *et al* 2018). Application by dusting is faced with the problems of wind sensitivity, requires large containers resulting in high transport and storage costs and also need special spraying equipment (Christos and Ilias 2011). Fumigation poses problem of extensive air pollution when fume chemicals are purposefully discharged into the environment for the reason that they destroy things (Warra and Prasad, 2020). According to the world health organization (WHO), about 1000,000 persons are affected by acute poisoning by contact with pesticide which can be highly hazardous. Each year, a death rate between 0.4 and 1.9% is recorded through highly hazardous chemicals (Jia *et al.*, 2020). There are also new methods of pesticide applications, such as ultralow volume (ULV) pesticide liquids, Electrodyne sprayers, fogging machines etc. as these reduce drudgery and environmental pollution and can help prevent an increase in the amount and toxicity of pesticides used in the environment (EPA 2015).

The mode of action of a pesticide has been reported to play a major factor in the efficacy of a pesticide (Aktar *et al*., 2009). As indicated in this study, Table 9 showed that contact action was the major mode of action of the pesticide applied in the study areas. The results obtained from this study is in agreement with the report of Sharma *et al*. (2019) that showed that contact pesticides were found to be used more widely and frequently worldwide than most other forms of action of pesticides. As shown in Table 10, herbicides were readily available than insecticides, fungicides and rodenticides. This is in agreement with the report of Mashingaidze (2004) that showed most farmers are encumbered with weed problems and hence this has caused the production of herbicides to be more than any other form of pesticides. In terms of marketability (Table 11), higher percentage of herbicides were readily sold (80%, 100%) in both Lafia and Makurdi, than insecticides (73.33%, 82.66%), respectively. This result is consistent with the studies from the Directorate-General for External Policies (2021), and Atwood and Paisley-Jones (2017), who found that herbicide sales were reported to be higher than sales of insecticides or any other kind of pesticides globally. In this study, the sales of herbicide were higher than other pesticides, this could be as a result of the ecological conditions of the study areas that made weeds to thrive better in the area because it receives more rainfall than most drier regions of the country. However, this report did not cover the use of herbicides in other ecological zones of the country.

CONCLUSION

Pesticides were assessed for their availability, types and uses and the propensity of banned pesticides for agriculture production in Lafia and Makurdi areas of Nasarawa and Benue States respectively. The study was also carried out to determine packaging forms, formulation, mode of application, mode of action and classes of pesticides available in the study areas. The study revealed that the major mode of packaging of pesticides was in litres. Emulsifiable concentrates constituted the highest form of formulation. The results showed that organophosphates were the major class of insecticides while glyphosates were the major class of herbicides. The results also revealed that majority of the pesticides were applied by spraying while the majority of the pesticides act as contact pesticides. In this study, the availability, type and uses of pesticides were determined and the various forms, sources of information about pesticide were observed. The study also examined the country of origin of these pesticides. The study went further to determine types of pesticides commonly used by farmers in the study areas and determined the availability of some banned pesticides in the study areas. The research recommends a strong promotion of the Integrated Pest Management Scheme as well as increased public awareness and knowledge of banned pesticides.

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CREDIT ACCESS AND ALLOCATIVE EFFICIENCY AMONG SOYBEAN FARMERS IN VANDEIKYA LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

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ABSTRACT

Due to opportunity cost, minimal allocation of fund to inputs ought to be generate optimum result. However, allocation is constrained by availability of fund, where equity is inadequate as is always the case. An alternative is credit. How allocatively efficient farmers are with or without credit has not been examined. Hence, this study examined the impact of credit access on the allocative efficiency of soybean farmers in Vandeikya Local Government Area of Benue State, Nigeria. Stratified random sampling technique was used to select 119 respondents. Primary data for the study were obtained with the use of questionnaire. Descriptive statistics, Cobb-Douglas frontier cost model and independent samples mean test, were used to analyze the data. Findings revealed that the majority (60.5%) of the farmers lacked access to credit, as 40.43% obtained credit from informal sources. In addition, the unit prices of land ($t=-2.50$, $p<0.05$) and herbicide ($t= 4.06$, $p<0.01$) were decreasing and increasing functions, respectively, of the total cost of production. Also, the return to scale parameter (0.4677) shows that production cost was a decreasing function of the factors in the model. The mean allocative efficiency was 0.31, leaving a shortfall of 69% in allocative efficiency. Both age ($p<0.05$) and education ($p<0.01$) increased allocative inefficiency among the respondents. The significance ($p<0.01$) of sigma-squared (σ^2) implied that the Stochastic frontier cost function fits the data more appropriately than the ordinary least method. Similarly, the significance ($p<0.05$) of gamma (γ) implied the existence of inefficiency effects. The result of the hypothesis revealed that farmers with access to credit had higher mean allocative efficiency. It was concluded that the farmers were highly allocatively inefficient as most of them lacked access to credit for procuring production inputs. It was recommended that investors and industries should avail soybean farmers of credit to enhance production; farmers should strive towards optimum resource mix with respect to factor prices.

Keywords: Credit, allocative efficiency, soybean, Cobb-Douglas

INTRODUCTION

Soya bean (*Glycine max* (L.) Merr) is a leguminous crop that is grown in tropical, subtropical and temperate climates either as food or cash crop (Wilson, 2015). It provides a relatively cheap and high-quality source of protein comparable to meat, poultry and egg (FAO, 2005). Asodina *et al*. (2020) stated that in rural economies of sub-Saharan Africa, where malnutrition and poverty are prevalent, including soybean food products in farm household diet has positive implications for children, pregnant and lactating mothers. As observed by Biam and Tsue (2013), soybean is a versatile crop from which products like soybean oil, soybean milk, soybean “fufu”, soybean “dadawa”, livestock feed, soyasauce and baby foods such as Golden Morn, Babeena, Nutrend and cerelac are derived. According to Chuffa et al. (2014), soybean have high amount of protein and oil, and they are used for diverse food products such as soy curd and fermented soy cakes (tofu and tempeh), soy sauce, soy paste (miso), and soy milk. The authors also noted that oil from soybean has positive implications for diabetic and cardiovascular diseases. Cheng (2017) added that soybean oil and protein are major products for food, livestock feeds, and industrial applications. Iticha (2020) surmised that soybean is a high-value and profitable crop. Osman *et al*. (2018) added that soybean is an important cash crop with the potential to reduce poverty.

Soybean in Nigeria is largely produced in the northern and southern Guinea savannah ecological zones, with Benue State as the major producer (Omoigui *et al*., 2020; Ugbabe *et al*., 2017). Available data from FAOSTAT show that between 2000 and 2019, Nigeria produced a total of 11,567,662 mt of soybean from 12,802,809 hectares of land. The quantity of oil produced from 2000 to 2018 was 466,300 mt. Thus, the yield is as low as 0.904 mt/ha. Some factors constrain production. For instance, Maniriho *et al*. (2022) stated that highly imperfect access to information (especially on the cost of inputs), and limited access to credit and insurance make subsistence agriculture a highly risky venture that is replete with uncertainty. Iwuchukwu and Beeior (2018) added that soybean is grown in many states of Nigeria using low agricultural input. Related to this challenge include input cost and quality. In recent times, the quality of some inputs like herbicides has been poor, whereas the price increased.

These challenges have implications for the level of allocative efficiency of farmers. Generally, efficiency entails a high level of optimum combination of resources for optimum production at the least cost that is possible (Abiola *et al*., 2021). Efficiency of a production unit may be defined as how effectively it uses variable resources for the purpose of profit maximization, given the best production technology available. Common efficiency measures include technical, allocative, profit and economic efficiency.
According to Dalhatu *et al*. (2018), allocative Efficiency (AE) refers to the adjustment of inputs and outputs to reflect relative prices, having chosen the production technology. The AE is basically the choice of an optimum combination of inputs consistent with the relative factor prices. Also, maximum or absolute allocative efficiency for a particular resource is confirmed if the efficiency for a particular resource is equal to one. In other words, allocative efficiency ranges between 0 and 1. The closer a given farmer’s allocative efficiency tends towards one, the closer the farmer is to optimum level of resource mix with respect to output and input prices. As the choice of an optimum combination of inputs consistent with the relative factor prices, Khalid *et al*. (2019) view AE as a ratio of economic efficiency to technical efficiency. Inoni (2007) held that the allocatively efficient level of production is where the farm operates at the least-cost combination of inputs. Konja *et al*. (2019) stated that an input is said to be efficiently utilized when it is put to the best possible use and at minimum cost. The foregoing presupposes that farmers’ access to farm capital, either equity or credit, is an important consideration in the application of funds to the various factors of production.

Degefa *et al*. (2017) held that credit utilized permits a household to enhance efficiency by removing money constraints which may affect their ability to apply inputs, implements and farm management decisions on time. In addition, credit availability can affect the decision to procure an apply optimum quantities of relevant inputs. Ali and Awade (2019) corroborated that access to credit can facilitate the purchase of equipment and inputs such labor, improved seeds and planting materials. The authors also emphasized that for a rational farmer, the decision of application for a credit should be based on the fact that the utility for having access to credit and getting the full amount that is requested is greater than the utility for not having access to the full amount that is requested. Abdallah (2016) added that credit access impedes farmers' access to productive resources and the adoption of new technologies, which could improve efficiency and agricultural development. Consequently, allocative efficiency could differ between farmers who have credit access and those who have not.

According to Osabohien *et al*. (2020), many farmers purchase most of their inputs in cash or from dealers on a credit-in-kind basis, leading to increased dependence of farm households on credit markets. Consequently, limited access to credit facilities, which hinders the adoption of more efficient and modern technologies in the farm operation. The obvious impact of credit access notwithstanding, Silong and Gadanakis (2020) emphasized that rural farmers' access to farm credit in Nigeria has been very low, with attendant adverse effect on farm performance. Ebukiba *et al*. (2020) implicated sub-optimal supply of agricultural inputs such as fertilizer and limited access to credit in Nigeria's food production constraint, especially soybean. As stated by Gawęda *et al*. (2020), soybean is a plant that is very sensitive to environmental stresses; consequently, optimal application of chemicals that would mitigate stress is of great importance in the cost structure of the commodity. Consequently, Goldsmith (2019) attributed the widespread low yields of soybean among SSA farmers a low input management system, including production credit. Upev *et al*. (2016) added that despite the efforts of Benue Agricultural and Rural Development Authority and other agricultural research institutes, soybean farmers are still not efficient in the use of available resources.

Empirical literature is awash with studies on allocative efficiency of various commodities. In some of these studies, credit access was an independent variable. However, the researcher is not aware of any study that tested the difference in allocative efficiency in soybean between farmers who have credit access and those who have not. It is from this perspective that this study will contribute to knowledge on allocative efficiency discourse. According to Awunyo-Vitor *et al*. (2016), empirical information from efficiency studies is useful for policy on resource utilization among farmers. Gona *et al*. (2020) asserted that efficiency has remained an important subject of empirical investigation particularly in developing economies where majority of the farmers are resource-poor.

The specific objectives of the paper were to analyze the credit access of soybean farmers in the study area, determine the factors that affect the cost of production among the farmers; and estimate the factors that influence allocative inefficiency among the respondents. It was hypothesized that credit access has no impact on allocative efficiency.

METHODOLOGY

Study Area

The study area was Vandeikya Local Government Area (LGA). It is one of the 23

LGAs in Benue State. Vandeikya Local Government Council is located between latitude 7°5' and 7°15' north of the Equator and Longitude 9° and 9°6' east of Greenwich. It has a landmass of 183,939 square metres (0.7 sq miles) with a population of well over 80,288. Vandeikya is in the South Eastern part of Benue State and shares boundaries with Obudu and Bekwara in Cross River State to the East, Ushongo to the North and Konshisha LGA to the West. There are twelve administrative council wards.

Vandeikya LGA was carved out of Gboko LGC in 1976. The indigenous community is the Tiv people who speak the Tiv language. The Vandeikya people are a hospitable group and are predominantly Christians, with a few traditionalists. Vandeikya Local Government area is dominated by undulating terrain, with much of the area being below 183 m (600 ft) above the sea level. Surface drainage is generally good, with almost all the rivers being seasonal, notably river Aya and river Be.

The climate is tropical sub humid with the mean annual rainfall of between 1,200 and 2,000 mm (47" and 79") averaging seven months in the year, while the mean annual temperature is 32.5 °C (90 °F). The wet season is from April to October or November while the dry season is November to March. Agriculture is the mainstay of the people; with arable land for sheep, goats and cattle rearing. Over 80% of the population are directly engaged in the peasant farming of virtually all major food crops, with concentration on rice, sweet potatoes, cassava, sorghum, citrus, spices, pepper, groundnut, soybean and bambara nuts.

The LGA is endowed with mineral deposits such as barites, kaoline and iron ores. Like most parts of the State, the soil is loose and well-drained loam with less clay fractions. According to Omoigui *et al*. (2020) and Vanger *et al*. (2021), this type of soil is suitable for soybean production. Being principally farmers, the major commercial engagements of the people in the area revolve around agricultural products. There are many small-scale cottage industries like rice milling, block making and furniture works and others. The settlement pattern is dispersed with thatched round houses. The Map of the study area is attached as Figure 1.

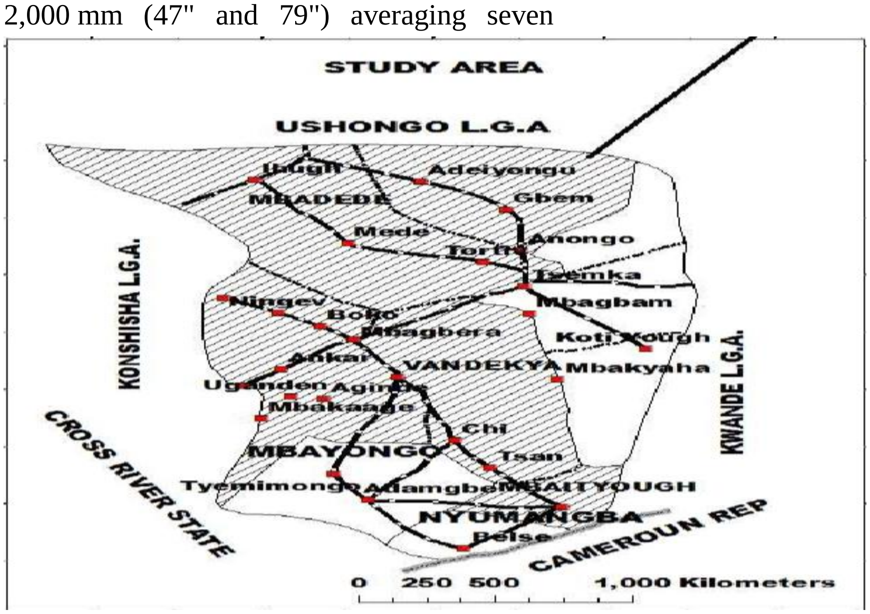

Figure 1: Map of the Study Area

Population and Sampling

The population for the study comprised all registered soybean farmers in the LGA, numbering 170. This was obtained through a reconnaissance survey. This number comprised 67 and 102 farmers with and without credit access, respectively. Stratified random sampling was used to select 47 and 72 farmers with and without credit access, respectively, for the study.

Data Collection and Analyses

Data for the study were primary in nature and collected with the aid of structured questionnaire. Afterwards, they were analyzed with the aid of frequency distribution to analyze credit access, Cobb Douglas frontier production function to determine allocative efficiency and independent samples test of means difference to determine the impact of credit access on allocative efficiency among the respondents.

Model Specification

The Cobb-Douglas Stochastic frontier cost function for the analysis of allocative efficiency was specified as follows:

$$lnY = \beta_0 + \beta_1 lnY * + \beta_2 P_1 + \beta_3 P_2 + \beta_4 P_3 + \beta_5 P_4 + V_i + U_i$$

where,

Y = log of total cost of production per hectare measured in Naria

Y* = total farm output per hectare measured in 100 kg bag equivalence

P_1 = unit price of seed measured in naira per kg

P_2 = unit price of land measured in naira per ha

P_3 = unit price of hired labour measured in naira per manday

P_4 = unit price of herbicide measured in naira per litre

Bs = parameters to be estimated

V =

U =

The model for allocative inefficiency is given as follows:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + +\delta_6 Z_6 + \delta_7 Z_7$$

The model for the independent samples t-test was given as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SX_1^2}{NX_1} + \frac{SX_2^2}{NX_2}}}$$

where,

$t = t - statistic$

$\bar{X}_1$ = $mean\ allocative\ efficiency\ of\ farmers\ with\ credit\ access$

$\bar{X}_2$ = $mean\ allocative\ efficiency\ of\ farmers\ without\ credit\ access$

SX_1^2 = $standard\ deviation\ of\ mean\ allocative\ efficiency\ of\ farmers\ with\ credit\ access$

SX_2^2 = $standard\ deviation\ of\ mean\ allocative\ efficiency\ of\ farmers\ without\ credit\ access$

NX_1 = $sample\ size\ of\ farmers\ with\ credit\ access$

NX_2 = $sample\ size\ of\ farmers\ without\ credit\ access$

RESULTS AND DISCUSSION

Credit Access and Source

The results of the analyses of credit access and source are presented in Table 1. The results show that the majority (60.5%) of the farmers lacked access to credit. This result is typical of farm production in Nigeria where most farmers cannot access credit facilities. Ogbanje *et al*. (2019) held that farmers in rural areas often lack access to credit facilities for meaningful production. Lack of access to credit can worsen the existing resource-poor status of farmers. The situation can reduce their capacity to acquire productive inputs at all or in the right quantities at the right time and prices. According to (Osabohien *et al*., 2020), lack of credit assistance can impose long-term hardship on farm households and impose restrictions on the purchase of critical inputs.

This finding is in line with Ogbanje *et al*. (2019) that most cassava farmers in Benue State lacked access to credit. Abdallah (2016) and Awotide *et al*. (2015) also reported low level of access to credit among farmers in Ghana and Nigeria, respectively. Furthermore, Osabohien *et al*. (2020) found that lack of access to credit among farmers cuts across the six geopolitical zones of Nigeria. In addition, Biam *et al*. (2016) found that majority (71.8%) of small-scale soybean farmers had no access to credit in Nigeria's central agricultural zone. However, the result is contrary to Akinbode (2013), who found that majority of rice farmers in Niger State had access to credit. Also, Akerele and Adekunmbi (2018) found that most farmers who were members of cooperative thrift had access to credit facilities. Similarly, Silong and Gadanakis (2020) found that most livestock farmers in Nasarawa State had access to credit.

Findings also show that most of the farmers who accessed credit got it from informal sources (40.43%). Informal sources of credit are more easily accessible to farmers due to their flexibility and compatibility with the needs and status of local farmers. This result is in line with Chandio *et al*. (2018) that most smallholder farmers obtained agricultural credit from informal sources. However, Moahid and Maharjan (2020) emphasized that credits from informal sources are replete with small amounts and short payback period.

Maximum Likelihood Estimates for Parameters of Stochastic Frontier Cost Model for Soybean Farmers.

The result of the maximum likelihood estimates for parameters of stochastic frontier cost model for soybean farmers is presented in Table 2. The result shows that the sigma-squared (σ^2) was low (0.08) but significantly different from zero ($p < 0.01$). In line with Ogbanje, *et al*. (2014), Biam *et al*. (2016) and Dalhatu *et al*. (2018), this result indicates goodness of fit and the correctness of the specified distributional assumption of the composite error terms in the estimated production model for soybean enterprises. In other words, the stochastic model is more appropriate for the data than the conventional ordinary least squares regression.

The estimated coefficient of herbicide (0.6377) was positive and statistically significant ($p < 0.01$). This means that herbicide is important in soybean production cost structure. The result also implies that the cost of soybean production increases by 0.64% as the unit price of herbicide rises by 1%. Due to the recent increase in demand for soybean by local vegetable oil processors and surge in the unit price of herbicide, coupled with fake products of the latter that flooded the market in 2022, herbicide was critical to production and invariably production cost. In addition, the repeated use of farmland encourages the prevalence of weeds, which necessitated more than the usual frequency of weeding of soybean plot. The result contravenes Biam *et al*. (2016) that using more agrochemical at higher prices was more cost effective than manual control of weeds.

The result further shows that the estimated coefficient of farmland (0.2235) was negative and statistically significant (0.05). The result implies that increase in the unit price of farmland decreases the overall cost of soybean production at the rate of 0.22%. As the price of farmland reduces, farmers can acquire more farmland to expand production and enjoy economies of scale. In peasant agriculture, unavailability of farmland due to the traditional tenure system inhibits production expansion. The inverse relationship also implies that using farmland, even at higher prices, is more cost effective than own farmland which is relatively more difficult to expand. It is important to stress that acquisition of more farmland requires more capital.

The return-to-scale parameter was found to be 0.4677. Given the specifications of the Cobb-Douglas frontier cost model, the results show that the elasticity of the mean cost of production was a decreasing function of the explanatory variables included in the model. This suggests that increase in the quantities of inputs at the prevailing prices would lead to a less than proportionate increase in the production cost. This also means increasing cost per unit of output and that farmers appears to be utilizing their inputs, given their prices. Therefore, this supposes that the farmers can minimize total cost of production at the current level of resources by cutting back input quantities to optimal levels, given the prevailing prices of inputs in cost model. This decreasing return-to-scale will ultimately lead to decrease in profit for the farmers.

Gamma (γ) was very high (0. 99) and statistically significant ($p < 0.05$). In line with Umeh *et al*. (2015), the result implies that the farmers were producing with inefficiency in cost allocation. As stated by Biam *et al*. (2016), the result also means that 99.87% of variability in the production cost of soybean farmers unexplained by the function is due to allocative inefficiency.

The result from the segment on inefficiency model in Table 2 shows that the estimated coefficients of age and education were both positive and significant at 1% level. The result implies that increase in these variables would lead to increase in the level of allocative inefficiency. As a farmer grows older, his strength dwindles. Consequently, he incurs higher cost of production to achieve relatively less output. Similarly, as a farmer acquires more education, he gives less to farming as his mental resources are channeled towards paid or white-collar job, with less drudgery. In the process, his ability to maximize cost allocative suffers setback.

Distribution of Respondents According to Allocative Inefficiency Estimates

Table 3 presents the distribution of respondents according to allocative inefficiency estimates. The result shows that the allocative efficiency estimate was skewed heavily in 0.08 to 0.03 range that represents 63.87% of the farmers. Similarly, there a wide variation between the farmers with minimum (0.08) and maximum (0.96) allocative efficiencies. These results, coupled with the low mean allocative efficiency of 0.31 show that most of the farmers are spending excessively on soybean production cost. The result also indicates a high level of imperfection in inputs' market. In other words, farmers are vulnerable to the exploitative tendencies of input dealers. While the allocative efficiency for the modal class ranged from 0.08 to 0.30, the highest allocative efficiency index was 96%. Thus, apart from the low level of allocative efficiency as observed among the farmers, none of the farmers attained full allocative efficiency. These results further show that there is plenty of opportunities for improvement on their current level of allocative efficiency. Furthermore and as articulated by Asogwa *et al*. (2011) and Wilcox *et al*. (2016), the farmers are yet to attain the level of optimal resource mix in their production process.

Precisely, the mean allocative efficiency in this study implies that soybean farmers have a shortfall 69% in allocative efficiency. Hence, there is much room for improvement in allocative efficiency among the respondents. This is higher than the 49.1% shortfall in allocative efficiency of an average soybean farmer in Taraba as found by Samuel and Idris (2021). However, the minimum and maximum allocative efficiencies in this study were higher than the 0.04 and 0.93, respectively in Samuel & Idris (2021) for soybean farmers in Taraba State.

Impact of Credit Access on Allocative Efficiency of Soybean Farmers

An independent samples t-test was run on a sample of 119 soybean farmers to determine if there was significant difference in allocative efficiency, which was represented by allocative efficiency estimates as obtained from the Stochastic frontier analysis. While the treatment group (farmers with credit access) constituted 39.5%, the control group (farmers without credit access) made up the remaining 60.5%. The results showed that farmers with credit access had higher mean allocative efficiency (0.44+-0.03) than those without credit access (0.22+-0.01). The t-ratio (9.2523) of the mean difference was statistically significant ($p < 0.01$). Hence, the study failed to accept the null hypothesis. Consequently, credit access has significant impact on allocative efficiency among soybean farmers in Vandeikya Local Government Area of Benue State. The implication of this result is that credit access enables farmers to allocate fund in a manner that can generate optimum result at the least possible cost. According to Abadallah (2016), credit at the disposal of farmers facilitates better mix and productivity.

Farmers who produced with credit facilities are conscious of the fact that the capital was procured at a cost and would be repaid with interest within a defined tenure. Therefore, this group of farmers make extra effort to procure inputs at the least possible cost. They are also conscious of the quality of the inputs that they procure for soybean production. As a result, they tend to minimize cost and maximize output more than those who produce the same commodity with only equity fund.

This result is in tandem with Osabohien *et al*. (2020) that households who had access to agricultural credit facilities had yields that are thrice those of their counterparts who did not benefit from such facilities. Yield is also a measure of efficiency. Ogwuike *et al*. (2022) indicated that it is an underlying strategy of the Sustainable Development Goals of the United Nations to increase the agricultural productivity and incomes of small-scale farmers through improved access to financial services and credit.

Table 1: Credit Access and Source (n=119, 47).

Credit access	Frequency	Percentage (%)
Had accessed	47	39.5
Lacked access	72	60.5
Source of credit		
Informal	19	40.43
Semi-formal	15	31.91
Formal	13	27.66

Source: Field survey, 2022

Table 2: Maximum likelihood estimates for parameters of the stochastic frontier cost model for soybean farmers

Variables	Parameters	Coefficient	Standard-error	t-ratio
Stochastic frontier				
Constant	β_0	9.1982	1.2285	7.49***
Log of Output	β_1	0.0349	0.1458	0.24
Unit price of seed	β_2	0.0603	0.1382	0.44
Unit price of land	β_3	(0.2235)	0.1039	(2.15) **
Unit price of hired labour	β_4	(0.0418)	0.0359	(1.16)
Unit price of herbicide	β_5	0.6377	0.1571	4.06***
Inefficiency model				
Constant	δ_0	0.3235	0.6832	0.47
Sex	δ_1	0.0056	0.0643	0.09
Age	δ_2	0.0308	0.0046	6.65***
Marital status	δ_3	(0.0721)	0.0525	(1.37)
Household size	δ_4	0.0083	0.0115	0.72
Farming experience	δ_5	(0.0128)	0.0069	(1.85)
Formal education	δ_6	0.0247	0.0061	4.07***
Membership of farmer-based organization	δ_7	(0.0509)	0.0642	(0.79)
Sigma-squared	(σ^2)	0.0810	0.0100	8.10***
Gamma	(γ)	0.9987	0.4313	2.32**
log likelihood function		(0.19)		
LR test of the one-sided error		91.24		

***t-ratio is significant at 1% level; **t-ratio is significant at 5%; *t-ratio is significant at 10%.

Table 3: Distribution of respondents by allocative efficiency estimates

Allocative efficiency	Frequency	Percentage (%)
0.08 < 0.30	76	63.87
0.30 < 0.52	27	22.69
0.52 < 0.74	12	10.08
0.74 < 0.96	4	3.36
Total	119	100
Minimum allocative efficiency	0.08	
Maximum allocative efficiency	0.96	
Mean allocative efficiency	0.31	

Source: Computed from Field Survey (2022)

Table 4: Impact of credit access on allocative efficiency estimates of soybean farmers

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Had access	47	0.44	0.03	0.19	0.39	0.50
Lacked access	72	0.22	0.01	0.06	0.20	0.23
Combined	119	0.31	0.02	0.17	0.27	0.34
Difference		0.22	0.02		0.18	0.27
Mean (Had access - Lacked access)					t = 9.2523	
Ha: diff != 0					Pr(|T| > |t|) = 0.0000	

CONCLUSION AND RECOMMENDATIONS

Majority of the farmers could not access credit for soybean production. The average soybean farmer in the study had a very low allocative efficiency estimate, with a shortfall of 69%. While the unit price of herbicide increased the total cost of soybean production, that of land had the opposite effect. Both age and formal education increased allocative inefficiency among the farmers. In the final analysis, farmers with credit access had higher allocative efficiency than those who had no credit access. Hence, a large space exist for soybean farmers to improve in the allocation of funds in a manner that they would obtain optimum result from minimal application of credit among inputs.

Consequently, it was recommended that investors and soybean companies make credit available to soybean farmers to boost their optimum resource mix and increased production of soybean. In addition, farmers should reduce soybean production in order to optimize production cost. Finally, aged and educated farmers should apply their wisdom, knowledge and experience in the procurement of soybean production inputs so as to cut down on the level of allocative inefficiency.

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PROFIT AND PRODUCTION FUNCTION ANALYSIS OF MILLET BASED CROPPING SYSTEM IN KATSINA STATE, NIGERIA

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ABSTRACT

Nigeria has a highly diversified agro-ecological condition which makes possible the production of a wide range of agricultural products including millet. The purpose of this study is to analyze millet based cropping enterprises that are more profitable, examine factors that influence millet based cropping output and to identify constraints associated with millet production in the study area. Primary data were obtained using structured questionnaires and interview administered on 196 randomly selected millet-based farmers in Katsina State, Nigeria. Descriptive statistics, net farm income and multiple regression models were used to achieve the research objectives. The result revealed that millet/sorghum/groundnut/cowpea (MSGC) farmers have the highest average farm size of 1.43 ha and majority (72.5 %) of the farmers were mostly engaged in the combination of MSGC. Results indicated that MSG farmers have the highest gross margin of ₦169,534.70 per hectare, net farm income of ₦147,567.10 and returns per naira invested of 3.27 per ha. The positive and statistically significant coefficients of seed in MSGC (0.009), MSG (0.211) and MSC (0.007) revealed that as the coefficients of these variables increase, the output from each enterprise also increases and vice versa. Result also revealed that inadequate extension delivery was the most critical constraint in all the millet based cropping systems. Millet intercropped farmers should liaise with extension agents to understand the principle, advantages and imbibe opportunity of millet based systems.

Keywords: Millet, extension agents, intercropping, legume.

INTRODUCTION

Nigeria has a highly diversified agro-ecological condition which makes possible the production of a wide range of agricultural products (Etonihu *et al.*, 2013). Agriculture is, therefore, one of the most important sectors of the economy. The sector is particularly important in terms of its contribution to Gross Document Product (GDP) and rural employment which stood at an average of 56 % and 65 % in 1960 – 1964 and 2012-2008 respectively (Oladimeji and Ajao, 2014). Although it remains unimpressive as it contributes about 22.35% of the country's Gross Domestic Product (GDP) in the first quarter of 2021, showing an increase of 1% point from the same quarter of 2020 (NBS, 2022a), agriculture still remains one of the largest sectors of the Nigerian economy.

Nigeria is one of the major millet producing countries in Africa with an average annual production of about 2.0 million tonnes in 2022

(FAOSTAT, 2022). The world average annual production of millet was reported to be 28 million tonnes, with India being the leading producer with 10.2 million tonnes (FAOSTAT, 2019). Millet is a very important cereal in the savannah areas in Nigeria, where it is fifth to rice, maize, wheat and sorghum in importance (FAOSTAT, 2019). Over 9 to 19 % of land sown annually to cereals is devoted to millet in Africa and Nigeria respectively (Jidda and Anaso, 2017; Ali *et al.*, 2018).

Like most agricultural enterprise, the chief objective of millet farm enterprise is the attainment of maximum profit with a given amount of inputs. In an attempt to maximize output and profit, Manyong *et al.* (2005), opined that the small-holder farmers are constrained by many problems including use of rudimentary production techniques, poor access to modern inputs and credits, poor infrastructure, inadequate access to market, land degradation, inadequate research and extension services. The continuing replacement of the crop by maize and sorghum also raises some questions as to whether it is profitable to grow the crop or not. This scenario calls for a critical assessment of the profitability, input-output relationship and constraints associated with the millet based production systems.

More importantly, Khapayi and Celliers (2016), argued that the measurement of profitability allows the farmers to access the farm businesses financial position and to chart its progress. Therefore, profitability statements are used as a basis for obtaining credit because they provide lenders with the information needed to evaluate loan applications.
According to Bello *et al.* (2011), diagnostic surveys of millet based production systems aim at identifying and describing the problems of the existing agricultural system in an area as an appropriate grass root or bottom-up strategy for developing new technologies that are appropriate to traditional farmer's needs and circumstances. Mixed cropping is the growing of two or more crops together on the same piece of land at the same time in a haphazard or systematic manner in such away that the growth of some or all of the component plant types overlaps in space and time. Generally, this is synonymous with inter-planting, inter-sowing, intercropping and crop mixture. The advantages of mixed cropping are enormous such as higher total yields than sole cropping even if yields of individual components are reduced, diseases and pests may not spread as rapidly in mixtures because of differential susceptibility to the pests and pathogens and mixed cropping may be used to suppress weeds, thereby reducing cost of weed control and improving the quality of products among others (Abubakar, 2014). Ironically, as advantageous as mixed cropping system is, it is not devoid of shortcomings. These includes: mechanization of planting, harvesting and other productivity-enhancing practices are more difficult if not impossible and the nutrient in the soil of mixed-crop farm are depleted yearly and given that smallholder farmers are extremely resource-poor, there is no hope of using inorganic fertilizers and adopting improved conservation methods to replenish the poor soils among others.

This study seeks to provide information on profitability and help farmers to identify millet-based enterprises that are more profitable and as well as examine factors influencing millet based cropping output because, farmers with limited resources have limited capacity to tolerate failure in production (Abubakar, 2014). Furthermore, researchers, policy makers, non-governmental organizations and international organizations as well as students may be able to use the outcomes of this study for future research; hence, it will serve as reference materials for future studies to obtain further information on the problems associated with millet-based production systems in the study area.

The following research questions therefore became necessary:

(i) What are the common millet-based cropping systems?
(ii) Is millet based intercropping profitable?
(iii) What are the factors influencing millet based cropping output?
(iv) What are constraints to millet based intercropping system in the study area?

RESEARCH METHODOLOGY

Description of the Study Area

The study area is Katsina State, located in the northern part of Nigeria, between Latitude 11^0 $07^{"}$ and 13^0 $22^{"}$ N and Longitude 6^0 $52^{"}$ and 9^0 $22^{"}$ E of the prime meridian (Kurfi, 2011). Using 3 % growth rate, the population is projected to 11,711,928 people in 2022 (NPC, 2006; NBS, 2022b). Although millet is grown where annual rainfall ranges between 200-1500 mm, the zone has a mean annual rainfall greater than 650 mm and it also grows well in areas with 250-700 mm (Abubakar, 2014, Vabi *et al.,* 2020). The mean annual temperature for the zone is in the range of 24 - 34 ^{0}C while the mean annual evapotranspiration is from 200 - 300 mm. Due to its resilience to drought stress, soil salinity / acidity and high temperature compared to other cereals, the crop can be grown during the dry months of March to May in the Sahel when temperature can rise up to, and above 40^{o}C (Kumara *et al.,* 2020). The climate conditions of the State vary considerably according to month and seasons. A dry season in the months of November to April and a rainy season from May to October.

Sampling Procedure and Data Collection

A three-stage sampling procedure was used for this study (Table 1). The first stage involved a purposive selection of 3 Local Government Areas (LGAs) in the State based on the predominance of millet-based production systems. These LGAs Sandamu, Mai'Adua and Daura. They are 24 villages in Sandamu, 65 villages in Mai'Adua and 29 villages in Daura LGAs who are involved in millet production based on the information collected from KTARDA (2018). In the second stage, 10 % of the villages from each LGA involved in millet production were selected randomly (Table 1). A reconnaissance survey was carried out with extension agents from Katsina State Agricultural and Rural Development Authority (KTARDA) to identify the farmers who practiced millet-based production systems in the selected villages. The farmers were grouped into five strata as follows:

(i) Millet / Sorghum (MS)
(ii) Millet / Sorghum / Groundnut / Cowpea (MSGC)
(iii) Millet / Sorghum / Groundnut (MSG)
(iv) Millet / Sorghum / Cowpea (MSC)
(v) Sole millet (SM)

From the population of farmers for each of production systems in each selected village, 10 percent were randomly selected aside from the sole millet farmers that were few in number and 10% of SM cannot give an adequate and statistical inference. Therefore, all of the sole millet farmers (25) on one hand and 10% each of MS (55), MSGC (37), MSG (52), and MSC (27) were randomly selected to give a total sample size of one hundred and ninety-six farmers as depicted in Table 1.

Data were collected from primary source. This was done using structured questionnaire administered to the selected millet-based farmers in 2017 / 2018 farming season. Data were obtained from these millet-based farmers on the socio-economic characteristics, inputs and output realized from the millet-based production system and constraints associated with millet-based production system in the study area.

Analytical Techniques

Net farm income was employed to determine the profitability of millet based production systems. This is expressed as:

$$NFI = \quad (1)$$

Where: *NFI* = net farm income of the millet-based farmers (₦); *GI* = gross income of the millet-based farmers (₦) and *TC* = total cost used by the millet-based farmers (₦).

$$TC = TVC + TFC \quad (2)$$

Where: *TC* = total cost used by the millet-based farmers (₦); *TVC* = total variable cost used by the millet-based farmers (₦) and *TFC* = total fixed cost used by the millet-based farmers (₦)

$$NFI_{ms} = (GI_m + GI_s) - (TC_m + TC_s) \quad (3)$$

$$NFI_{msgc} = \left(GI_m + GI_s + GI_g + GI_c\right) - \left(TC_m + TC_s + TC_g + TC_c\right) \quad (4)$$

$$NFI_{msg} = \left(GI_m + GI_s + GI_g\right) - \left(TC_m + TC_s + TC_g\right) \quad (5)$$

$$NFI_{msc} = (GI_m + GI_s + GI_c) - (TC_m + TC_s + TC_c) \quad (6)$$

$$NFI = GI – TC \quad (7)$$

Where: *m* = millet; *s* = sorghum; *g* = groundnut; *c* = cowpea

Equations 1 to 7 follow Olukosi & Erhabor, (2005); Chidiebere-Mark *et al.* (2014); Oladimeji *et al*. (2018).

Production function was developed to determine factor influencing millet based cropping output that is, determine the physical relationship between inputs and output and used to compare the relative importance for common resources used in millet crop mixtures. Multiple regression model was used to determine the production factors affecting output of millet based production systems. The equation was expressed explicitly as the Cobb-Douglas production function:

$$logY = \beta0 + \beta1logX1 + \beta2logX2 + \beta3logX3 + \beta4logX4 + \beta5X5 + U \dots\dots\dots\dots\dots (8)$$

Equation 8 adopted from Oladimeji *et al.* (2013).

Where Y = crops output in grain equivalent weight (GEW) for millet based output (kg). Sorghum, groundnut and cowpea were converted to millet grain equivalent (adopted from Clark and Haswell, 1970 cited in Iheanacho, 2000 and Abubakar, 2014), β_0 = intercept, X_1= seed (kg), X_2= fertilizer (kg), X_3= agrochemical (litre), X_4= labour (man-days), X_5= land (ha) and μ_i =error term

RESULTS AND DISCUSSION

Millet-Based Production Systems in the Study Area

The different millet-based production systems identified by the farmers are shown in Table 2. The result revealed that majority of the farmers (72.5 %) were mostly engaged in the combination of MSGC. The uncertainty of harvest (yield) due to the changing climatic conditions may have contributed to the farmer's choice of more crop combination.

The choice of four different crop mixtures has an added advantage of resource utilization of land. Only 2 % of the farmers planted millet solely. This result agrees with Abubakar (2014), who found in a study that millet, sorghum, groundnut and cowpea were the most important crops in the northern part of Katsina State; and 4-crop mixtures were more prevalent in the zone than sole, 2-crop mixtures and 3-crop mixtures.

Furthermore, majority of the farmers (91.9 %) might have known the importance of legumes in agriculture and that could be a good reason why most farmers opted to plant at least one legume crop alongside millet. Alex *et al.* (2011), and Bano and Iqbal (2016), opined in their various studies that agricultural systems have traditionally relied much on legumes for nitrogen input in the soil. Nitrogen being an inert gas cannot be used by plants, animals and micro-organisms and therefore legumes help to convert the nitrogen gas into its usable form like ammonia which can be used by the plants and other organisms.
Table 3 shows that MSGC farmers have the highest average farm size with 1.43 ha. This implies that MSGC farmers are more than other crop combination in term of farm size. Sole millet farmers have the lowest average farm size with 0.30, and this implies that sole millet farmers do not have adequate farm size to accommodate more than one type of combination. This result is similar to Chidiebere-Mark *et al.* (2014), in the study of profitability of cassava-based crop farmers in Owerri agricultural zone of Imo State, South-East Nigeria.

Profitability of Millet-Based Production Systems

Results presented in Table 4 indicate that MSC has the highest gross margin of ₦169,534.7 per hectare, net farm income of ₦147,567.1 and returns per naira invested of 3.27 per ha. This is due to the fact that cost expended on labour is lower in MSC system than that of other enterprises. This is in line with the findings of Ali *et al.* (2018), who observed that labour accounts for 61 % of cost of millet production in Funakaye LGA, Gombe State, Nigeria

The rate of returns on investment (return per naira invested, RNI) for MS was 1.66, indicating that for every ₦1 invested in millet / sorghum production in the study area a profit of ₦0.66 was made. The RNI for MSGC was 2.83, suggesting that for every ₦1 invested in MSGC production in the study area a profit of ₦1.83 was made. The RNI for MSG was 2.53, revealing that for every ₦1 invested in MSG production in the study area a profit of ₦1.53 was made. The RNI for MSC was 3.27, indicating that every ₦1 invested in MSC production in the study area, a profit of ₦2.27 was made. The RNI for SM was 1.56, implying that for every ₦1 invested in SM production in the study area a profit of ₦0.56 was made. Thus, it could be concluded that millet based production in the study area was economically viable.

Production Factors Affecting Output of Millet Based Production Systems

The Cobb-Douglas production function was selected to explain the relationship between output and inputs used in millet-based production systems. Among the production functions tried which include linear, semi-log, reciprocal. Cobb-Douglas has the best fit. Table 5 shows the results of regression coefficients obtained from the multiple regression analysis based on different systems. This explained production factors affecting output of millet based production systems. The results revealed that about 0.593, 0.521, 0.506, 0.542 and 0.665 units of the variation in one unit of output for MS, MSGC, MSG, MSC and SM, respectively were explained by their respective factors inputs included in the their models. The positive and statistically significant coefficients in all the models revealed that the output realized from each production system is directly related to the inputs used. This can be explained by noting the fact that as the coefficients of these variables increase, the output from each enterprise also increases. On the other hand, the output realized is negatively related to the amount of fertilizer in MSG and MSC, labour and land in SM. That is, as the values of these variables increase, the output realized from the enterprise decreases.

Production Elasticity of Input

Elasticity of production (EoP) measures the degree of responsiveness of output to a change in input. The results in Table 5 revealed that EoP for MS was greater than one (1.08), that is, the farmers is experiencing increasing returns to scale. On the other hand, the EoP for millet based cropping systems including MSGC (0.764), MSG (0.746), and MSC (0.515) is positive and less than one, this imply that the millet production is experiencing decreasing return to scale. However, the EoP for SM is negative (-0.56) show that the inputs are being over-utilized.

Constraints to Millet-Based Production Systems

The constraints faced by millet-based farmers in the study area were disaggregated based on each production system as depicted in Table 6. Thereafter, it was ranked from most critical to the least according to their severity as indicated by the farmers in their different enterprises. Result revealed that inadequate extension delivery was a common factor and most critical in all the millet based systems with MS (16.4 %), MSGC (21 %), MSG (17.1 %), MSC (18.6 %) and SM (16 %). This implies that most farmers who are ready to communicate and need the help of extension agents to adopt new agricultural technological innovations to improve their farms cannot do so because they have no access to extension services. According to Danso-Abbeam *et al.* (2018), in agricultural-dependent economies, extension programmes have been the main conductor for disseminating information on farm technologies, supporting rural adult learning and assisting farmers in developing their farm technical and managerial skills.

Pest and diseases attack were the second most critical constraints found in MSG and SM enterprises with 17.1 and 16 % respectively and ranked also second in MSGC with 19.2 %. This implies that crops are susceptible to attack by numerous pests and diseases throughout the life cycle which are responsible for pre-harvest and postharvest losses. Therefore, effective control of these is necessary if reasonable yield is expected as pest and disease automatically cause a serious decline in quality thereby leading to a reduction in product price. This finding agrees with Ismaila *et al.* (2010), who opined that pest and diseases attack is highly responsible for poor yield in the study of cereal production in Nigeria. It is estimated that worldwide up to 30 % of agricultural production is lost to animal pests, weeds and diseases each year with losses in tropical regions higher than in temperate areas (Abubakar, 2014).

Inadequate capital was also ranked high in SM (1^{st}) and MSC (2^{nd}) with 16 and 17.8 % respectively. It was ranked fairly high in MS (4^{th}) with 13.7 %, MSGC (5^{th}) with 8.7 % and MSG (6^{th}) with 10 %. This implies that difficulty in securing loans due to high interest rates, inadequate loan amounts and collateral requirements by the banks are some of the major reasons to low access to credit in the area. Credit is a very strong factor that is needed in an agricultural production enterprise and its availability could determine the extent of production capacity. According to Ogbonna *et al.* (2014), lack of capital and credit prevents farmers from acquiring inputs technologies vital for raising productivity

Table 1: Distribution of millet-based farmers in the study area

		Sample population						Selected sample (10%)					
LGA	Village	MS	MSGC	MSG	MSC	SM	Total	MS	MSGC	MSG	MSC	SM	Total
Sandamu	Fago	50	24	45	16	2	155	5	2	5	2	2	16
	Sandamu	35	30	33	22	2	143	4	3	3	2	2	14
Mai'Adua	Bula	30	30	40	25	1	136	3	3	4	3	1	14
	Daba	40	36	32	29	2	158	4	4	3	3	2	16
	Mai-baga ruwa	41	34	45	30	1	164	4	3	5	3	1	16
	Koza	39	33	40	21	2	149	4	3	4	2	2	15
	Tuga	50	25	44	19	3	168	5	3	4	2	3	17
	Wala	33	29	22	23	2	123	3	3	2	2	2	12
Daura	Kalgo	77	44	79	34	3	264	8	4	8	3	3	26
	Madobi	80	48	74	27	4	267	8	5	7	3	4	27
	Mazoji	70	38	67	23	3	228	7	4	7	2	3	23
Total		545	371	521	269	25	1955	55	37	52	27	25	196

Source: Katsina State Agricultural and Rural development Authority (KTARDA), 2017/2018. Note: MS = millet/sorghum, MSGC = millet/sorghum/groundnut/cowpea, MSG = millet/sorghum/groundnut MSC = millet/sorghum/cowpea and SM = sole millet

Table 2: Distribution of farmers based on millet based cropping systems

Millet-based production system	Frequency	Percentage (%)
Millet / sorghum (MS)	12	6.1
Millet / sorghum / groundnut/cowpea (MSGC)	142	72.5
Millet / sorghum / groundnut (MSG)	12	6.1
Millet / sorghum / 8cowpea (MSC)	26	13.3
Sole millet (SM)	4	2.0
Total	196	100

Table 3: Distribution of millet-based enterprises based on their farm size

Millet-based enterprise	Frequency	Percentage	Ave farm size (ha)	Min (ha)	Max (ha)
M/S	12	6.1	0.70	0.3	1.5
M/S/G/C	142	72.5	1.43	0.3	9
M/S/G	12	6.1	1.03	0.3	2.4
M/S/C	26	13.3	0.80	0.2	1.5
Sole millet	4	2	0.30	0.3	0.3
Total	196	100	1.25	0.2	9

Table 4: Profitability of millet-based production systems

Cost of Variable, ₦/ha	MS	MSGC	MSG	MSC	SM
seed	6,495.39	14 341.53	15 368.5	12 964.86	4,062.4
labour	25 115.4	42 606.34	36 475	22 321.23	24 800
fertilizer	4,630	9,363.42	4,335.26	5,779.17	7,500
pesticides	1,366.22	3,185.43	1,316.67	1,900	2,355
herbicides	-	-	-	-	3,305
TVC	37 607.01	69 496.72	57 495.43	42 965.26	42 022.4
land	19 384.62	2,1704	1,5375	12 057.69	18 000
machinery	6,700	4,483.47	3,244.17	9,909.96	6,175
TFC	26 084.62	26 187.47	18 619.17	21 967.65	24 175
TC	63 691.63	95 684.19	76 114.6	64 932.91	66 197.4
Gross income (GI)	105 890.3	228 000	192 641.7	212 500	103 500
Gross Margin	68 283.32	158 503.3	135 146.2	169 534.7	61 477.6
Net Farm Income	42 198.7	132 315.8	116 527.1	147 567.1	37 302.6
RNI	1.66	2.38	2.53	3.27	1.56
Operating Ratio	0.36	0.30	0.30	0.20	0.41
Fixed ratio	0.25	0.11	0.10	0.10	0.23
Gross ratio	0.60	0.42	0.40	0.31	0.64

Table 5: Production factors affecting output of millet based production systems

Variable	MS	MSGC	MSG	MSC	SM
			β (P > /Z/)		
seed	0.209 (0.159)	0.009(0.067)	0.211 (0.09)	0.007 (0.025)	0.003 (0.116)
fertilizer	0.400 (0.000)	0.005 (0.100)	-0.008 (0.057)	-0.528 (0.06)	0.035 (0.000)
agrochemical	0.387 (0.182)	0.127 (0.000)	0.003 (0.106)	0.621 (0.002)	0.186 (0.298)
labour	-0.008 (0.085)	0.621 (0.003)	0.487 (0.003)	0.412 (0.001)	-0.05 (0.008)
land	0.092 (0.052)	0.002 (0.001)	0.053 (0.074)	0.003 (0.000)	-0.73(0.076)
R^{-2}	0.593	0.521	0.506	0.542	0.665
F-value	45.09	38.45	32.07	41.03	49.02
EoP	1.08	0.764	0.746	0.515	-0.56

Figures outside parenthesis are β (coefficient) and in parenthesis are (P > /Z/), EoP denote elasticity of production

Table 6: Constraints of millet-based production systems in Katsina State, Nigeria

Constraints	M/S	M/S/G/C	M/S/G	M/S/C	Sole millet
pest and diseases attack	10 (13.7) 4th	53 (19.2) 2nd	12 (17.1) 1st	14 (11.9) 4th	4 (16) 1st
Late rainfall & climate variability	12 (16.4) 1st	16 (5.8) 8th	4 (5.7) 8th	3 (2.5) 9th	3 (12) 5th
Inadequate and untimely supply of inputs	11 (15.1) 3rd	19 (6.9) 6th	-	11 (9.3) 5th	-
Inadequate credit/capital	10 (13.7) 4th	24 (8.7) 5th	7 (10) 6th	21(17.8) 2nd	4 (16) 1st
Lack of extension service delivery	12 (16.4) 1st	58 (21.0) 1st	12 (17.1) 1st	22 (18.6) 1st	4 (16) 1st
Lack of efficient post-harvest storage facilities	4 (5.5) 8th	25 (9.1) 4th	6 (8.6) 7th	10 (8.5) 6th	3 (12) 5th
High cost of labour	5 (6.9) 7th	17 (6.2) 7th	10 (14.3) 4th	8 (6.8) 7th	3 (12) 5th
High cost of improved seed/poor seed varieties	9 (12.3) 6th	53 (19.2) 2nd	11 (15.7)3rd	21(17.8) 2nd	4 (16) 1st
High cost of transportation	-	11 (4.0) 9th	8 (11.4) 5th	8 (6.8) 7th	-
Total	73 (100)*	276 (100)*	70 (100)*	118 (100)*	25 (100)*

Multiple responses; M= millet; S= sorghum; G= groundnut; C= cowpea, Note: Figures in parentheses are the percentage

Lack of storage facilities was also identified as an impediment to millet based production systems. This was fairly ranked in MSGC (4th) with 9.1 %, SM (5th) 12 % and MSC (6th) with 8.5 %. It was ranked relatively low in MSG (7th) with 8.6 %, MS (8th) with 5.5 %. By way of implication, lack of storage facilities will limit the availability of produce. This is in accordance with Abubakar (2014), who found out that lack of storage facilities limits the steady availability of produce and stable market of food prices, prevents farmers and producers from selling their produce at times when they can get best prices; increases losses in quality and quantity and prevent healthy seeds from being made available for planting in the next cropping season.

Inadequate rainfall was also a constraint in MS with 16.4 %. It was fairly ranked high in sole millet as 5th with 12.0 %. It was ranked low in MSGC and MSG as 8th with 5.8 and 5.7 % respectively and ranked 9th in MSC with 2.5 %. Inadequate rainfall is a major constraint because majority of the farmers are not into any form of irrigation scheme to help in their production. This findings agree with Fagarigba *et al.* (2018), who found out in a study that low rainfall couple with high temperatures increase the frequency of the dry-up of water bodies such as wells, dams and streams.

Inadequate and untimely supply of inputs was ranked as high as 3rd in MS with 15.1 %. It was also fairly ranked high in MSC (5th) and MSGC (6th) with 9.3 and 6.9 % respectively. By way of implication, delayed supply of input will obstruct performance in production. This finding agrees with Ogbonna *et al.* (2014), who in a study identified delay in input supply as a major constraint to effective farming and extension performance in green river project of Imo and Rivers states and such was reported to be capable of posing a hindrance to the effective performance in production.

This was fairly ranked high in MSG (4th) with 14.3 % and SM (5th) with 12 %. It was 7th in MS (6.9 %), MSGC (6.2 %) and MSC (6.8 %). This implies that when cost of labour is high it hinders the farmers from putting full labour commitment on their farms thereby limiting productivity. This finding is similar to Simonyan and Obiakor (2012), who found high cost of labour to be a major constraint in agricultural production in Nigeria.

High cost of improved seed/poor seed varieties was ranked high in SM (1st) with 16 %, MSC (2nd) with 17.8 %, MSGC (2nd) with 19.2 % and MSG (3rd) with 15.7 %. MS was fairly ranked in 6th with 12.3 %. By way of implication, it means the farmers are stuck with planting old varieties which are more susceptible to pest and diseases attack, which in turn leads to poor yield. This finding agrees with Dawud *et al.* (2017), who opined that most farmers have little or no access to improved seeds because of how costly they are and continues to recycle seeds that have become exhausted after generations of cultivation.

CONCLUSION AND RECOMMENDATIONS.

From the findings in this study, it can be concluded that MSGC system was the most widely practiced millet-based production systems in the study area. It also reveals that millet-based production systems in the study area are profitable. However, production factors that statistically influence output among millet based production patterns varied from one enterprise to another. The millet based production systems offered a good knowledge on profitability and associated constraints for farmers who intend to adopt the models. This is in addition to established anticipated advantages of millet based production systems such as higher total yields than sole cropping, and the latent effects may include sustainability of soil, weed and pests' suppression, and insurance against crop failure among others. It is recommended that millet intercropped farmers should liaise with extension agents to understand the principle, advantages and imbibe opportunity of millet based systems.in order to improve the productivity of millet based production systems in the study area. Farmers should also strengthen their cooperative to enable them access credit through formal credit institution and non-governmental organisation (NGOs).

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PROFITABILITY ANALYSIS OF ORGANIC AND NON –ORGANIC *Cucumis sativus* FARMING IN YABA COLLEGE OF TECHNOLOGY, EPE CAMPUS, LAGOS STATE

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ABSTRACT

The agricultural sector is faced with various challenges especially in the aspect of suitable farming system. Hence, this study was carried out to determine the comparative analysis of profitability of organic and non-organic cucumber (*Cucumis sativus*) farming in Yaba College of Technology, Epe campus, Epe, Lagos State. The experiment was laid out in Randomized Complete Block Design (RCBD) with three (3) treatments and three replicates hence, there were 9 experimental plots. While gross margin, net profit and rate of return were used to analyze the data. Results showed that there was significant difference in the application of organic and non-organic treatments in terms of Number of leaves (organic: 15.4, non-organic: 14.8, control: 13 respectively), Leaf area (organic: 24.6, non-organic: 19.6, control 13.2 respectively), Number of fruit (organic: 12.4, non-organic: 11.5, control: 4.4 respectively) and Fruit weight (organic: 1.0kg/0.0075ha, non-organic: 0.8kg/0.0075ha, control: 0.4kg/0.0075ha respectively). The organic system incurred a cost of ₦3,600.00 and rate of return of 59kobo/0.0075ha followed by non-organic system ₦3,570.00 and 63kobo/0.0075ha, respectively while the control system incurred a cost of ₦-700.00 and -0.19kobo/0.0075ha, respectively. The study therefore concluded that the non-organic cucumber realized the highest rate of return followed by the organic system in the study area. It is therefore recommended that for a higher rate of return, farmers should cultivate cucumber using non-organic system.

KEYWORDS: Comparative, Profitability, Organic and Non organic

INTRODUCTION

The Nigerian economy is diversifying from the oil sector into the agricultural sector. Agriculture is the major means of livelihood of about 70% of her populace (World Bank, 2001). The agricultural sector in Nigeria accounts for about 30% of the total gross domestic product, it also serves as a major activity for Nigeria's economy after oil (Statistis, 2023). It still stands as the largest employer in Nigeria with an employment rate more than 36% of the labour force (Taiwo, 2020).

However, the performance of agricultural sector in the last few decades remained far from expectations in terms of efficient crop production. The extent, to which the expected roles have been adequately played, lies greatly in the agricultural productivity (Nenna, 2014) and agricultural practices such as organic farming (OF) which is an integrated production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasizes the use of natural inputs (i.e. mineral and products derived from plants) and the renunciation of synthetic fertilizers and pesticides (FAO/WHO, 2007). Symbiotic life forms are cultured ensuring weed and pest control and optimum soil biological activity, which maintain fertility. On the other hand, non-organic farming is a confusing term that the agrochemical industry uses to clear issues against chemical farming. The more accurate term to describe chemical farming is non-organic farming. In chemistry, the opposite term is inorganic, for compounds that do not contain carbon. In farming, the opposite term is non-organic, for production systems that do not sustain the health of soils, ecosystems and people, and are instead harmful to them (Roberto, 2011). Non-organic farming is an agricultural production method which involves the use of manmade products such as pesticides, herbicides, fungicides in production

Cucumber (*Cucumis sativus*) is a widely cultivated plant in the gourd family, known as *Cucurbitaceae*. It is a creeping vine that bears cucumiform fruits that are used as vegetables. There are three main varieties of cucumber known which includes; slicing, pickling, and seedless. Within these varieties, several cultivars have been created. The cucumber is originally from South Asia, but now grows on most continents. The cucumber is a creeping vine that roots in the ground and grows up trellises or other supporting frames, wrapping around supports with thin, spiraling tendrils (Mariod *et al.,* 2017). The plant may also root in a soilless medium and will sprawl along the ground if it does not have supports. Most African soils are fragile and low in fertility (IFDC, 2005) and they are unable to support reasonable agricultural production (Singh, 2003).

Production of agricultural commodities is faced with various challenges especially in the aspect of suitable farming system, land degradation, inefficient resources, irrigation, and climate among others. Agricultural production cost is increasing day by day. For example, access to inputs (seeds, fertilizers etc.) has been restricted by high cost and scarcity among rural farmers in Nigeria. Among rural farming, this rising cost affects profitability. Profitability (defined as the level of farm profits) differs from relative profitability of an organic farm, which refers to the changes in the relation of agricultural income of organic farms to the agricultural income of non-organic farms. Differences in prices, yields, production costs, direct payments and non-agricultural outputs are identified as the main determinants of the relative profitability of organic farms (Sanders, 2007). Profitability certainly depends on the crop choice, which of course is determined partly by environmental conditions and partly by the demand for products and available governmental programs supporting such crops (Noemi, 2009).

However, the selection of the comparison group; soil type, yield, management practice are expected to have a strong influence on profitability. Increased profitability of agricultural produce depends on consumer demand and market prices. Thus, this study aims at comparing the yield and analyzing the profitability of organic and non-organic farming of cucumber.

METHODOLOGY

The experiment was carried out on the teaching and research farm at Yaba College of

Technology, Odoragunshi, Epe campus which lies between latitude 6.58^0N and longitude 3.98^0S in Epe Local Government area, Epe, Lagos State, Nigeria. The experimental design used for this study was randomized complete block design (RCBD). This is because RCBD is used for open field experiments and it also allows the use of blocks which prevents one treatment from affecting the other, with three (3) blocks and three (3) replicates. The first block received the organic treatments (animal droppings) while the second block received the non-organic treatments (synthetic fertilizer) and the last block, which served as the control block, received no treatments. Manual weeding method was used to control all the blocks. Thirty (30) stands of plants were randomly selected and tagged per treatment for determination of growth and yield performance. The parameters assessed include; Number of leaves, leaf area (cm) and fruit weight (kg), each parameter was collected at 2, 4, 6 and 8 weeks after planting. Data collected were analyzed using descriptive statistics, gross margin, net profit and rate of return to determine the profitability of the cucumber production, while Analysis of Variance (ANOVA) was used compare the differences in production.

i. Gross margin.
Revenue from GM=TR-TVC
GM=Gross margin (₦/ha)
TR=Total cucumber revenue (₦/ha) = unit selling price x output
TVC=Total variable cost (₦/ha).

ii. Net profit analysis.
Net profit= TR - TC
TR = Total Revenue (₦/ha)
TC=Total cost (₦/ha)

iii. Rate of return analysis.

$$RRA = \frac{\text{Net profit}}{\text{Total cost}} \times \frac{100}{1}$$

RESULTS AND DISCUSSION

Physico-Chemical Characteristics of the Soil

Table 1 shows results of soil chemical and nutrient composition of the soil. It shows that the soil was acidic with pH (3.91); the soil texture has silt and clay below (25%) and high percentage of sand. Calcium and magnesium are low (13.88 and 0.46 respectively) where the required amount of calcium and magnesium in the soil is 50% and 10% respectively; it is low in nitrogen and potassium.

Agronomic and Yield Parameters

The study revealed that there were appreciable differences in the application of organic and non-organic materials in terms of number of leaves, leaf area at 2, 4, 6 and 8 weeks respectively, number of fruits and fruit weight. This agrees with the report of Aduloju *et al.* (2010) and Dada and Fayinminu, (2010) that nutrients from mineralization of organic matter promoted the growth and yield of cucumber. Also, the application of organic and non-organic fertilizer enhanced cucumber agronomic performances. The results in Table 2 show the mean and standard deviation of leaf area, fruit weight, number of leaves and number of fruits for each treatment. The table shows that the organic treatment has the highest value in all parameters measured with mean and standard deviation of; Leaf area: 24.6 cm and 3.4 cm, fruit weight: 1.0kg/0.0075 ha and 0.2kg/0.0075 ha, number of leaves: 15.4 and 5.8, number of fruits: 12.4 and 2.8 respectively, while the non-organic shows a mean and standard deviation of ; 19.6 cm and 4.2 cm for leaf area, 0.8kg/0.0075 ha and 0.2kg/0.007 5ha for fruit weight, 14.8 and 5.4 for number of leaves, 11.4 and 2.6 for number of fruits, respectively, and the control method had a mean and standard deviation of ;

13.2cm and 3.2cm for leaf area, 0.4kg/0.0075ha and 0.08kg/0.0075ha for fruit weight, 13 and 4.8 for number of leaves, 4.4 and 2.0 for number of fruits, respectively.

The increase in the number of leaves, size of leave, number of fruit and fruit weight of the organic treatment can be attributed to the ability of organic treatments to promote vigorous growth, increase physiological activities in the plant, due to supply of plant nutrient and improvement in soil properties, thereby resulting in the synthesis of more photo-assimilate which is used in producing fruits. This is in agreement with the findings of Sanni *et al.* (2013) and Duruigbo (2016) that the use of organic manures for the production of vegetable crops proved to be effective.

Table 1: soil analysis result of the study area

PARAMETERS		Values
	pH	3.91
Particle Size (%)	Sand (%)	78.81
	Silt (%)	14.8
	Clay (%)	6.7
Exchangeable bases	Ca (%)	13.88
	Mg (cmol)	0.46
	Na (cmol)	0.04
	K (cmol)	0.04
Acidity	$A1^{+} + H^{-1}$ (cmol)	0.18
E.C.E.C	(cmol)	14.85
Base Saturation		98.39
Macro-nutrient	N (%)	0.06
	Mg (%)	0.66
	Av. P (MgKg)	19.46
Micro nutrients	Fe (MgKg)	24.53
	Cu (MgKg)	1.22
	Zn (MgKg)	2.43
	Mn (MgKg)	5.26

Source: Computed from experimental data, 2019

Table 2: Descriptive statistics of parameter measured

Parameters	Treatment	Mean	Std. Deviation
Leaf Area	Organic	24.6	3.4
	Non-organic	19.6	4.2
	Control	13.2	3.2
Fruit Weight	Organic	1.0	0.2
	Non-organic	0.8	0.2
	Control	0.4	0.08
Number of Leaves	Organic	15.4	5.8
	Non-organic	14.8	5.4
	Control	13	4.8
Number of fruits	Organic	12.4	2.8
	Non-organic	11.4	2.6
	Control	4.4	2.0

Source: Computed from experimental data, 2019

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Profitability Analysis of Cucumber Production

The result of the profitability analysis of organic, non-organic and control system of cucumber produced for the season is presented in Table 3.

Profitability Analysis of Cucumber Planted Under Organic System

The result for profitability analysis of cucumber planted under organic system is shown below. The gross margin, net profit and rate of return on investment was computed as follows.

Gross margin= total revenue - total variable cost
= ₦9750 – ₦5100
= ₦4650
Net profit = total revenue – total cost
= ₦9750 – ₦6150
= ₦3600

Rate of return on investment
$= \frac{\text{Net profit of investment}}{\text{Total cost on investment}} \times 100$
$= \frac{3600}{6150} \times 100$
= 0.59kobo
= 59%

The total revenue generated, the total fixed cost and variable cost from the organic cucumber production in the study area gives a gross margin of ₦4,650 and a net profit of ₦3600. The rate of return of 0.59% implies that, for every ₦1 spent on organic cucumber farming, a profit of 59Kobo/0.0075ha was realized. This indicated that organic cucumber farming system was profitable in the study area. This is in line with the study of Duffy *et al.* (2002) that organic farming system has high yield when compared to other farming system.

Profitability Analysis of Cucumber Planted Under Non-Organic System

The result for profitability analysis of cucumber planted under non-organic system is shown below. The gross margin, net profit and rate of return on investment was computed as follows.

Gross margin= total revenue - total variable cost
= ₦9220 – ₦4650
= ₦4570

Net profit = total revenue – total cost
= ₦ 9220 – ₦1000
= ₦3570

Rate of return on investment
$= \frac{\text{Net profit of investment}}{\text{Total cost on investment}} \times 100$
$= \frac{3570}{5650} \times 100$
= 0.63kobo
=63%

The total revenue generated, the total fixed cost and variable cost from the non-organic cucumber production in the study area gives a gross margin of ₦4,570 and a net profit of ₦3570. The rate of return of 0.63% implies that, for every ₦1 spent on organic cucumber farming, a profit of 63Kobo/0.0075ha was incurred. This indicated that organic cucumber farming system was profitable in the study area. This is in accordance with the findings of Willer and Kilcher (2009) that non-organic farming system is easy to cultivate and produce high yields when compared with other farming systems.

Profitability Analysis of Cucumber Planted Under Control System

The result for profitability analysis of cucumber planted under control system is shown below. The gross margin, net profit and rate of return on investment was computed as follows.

Gross margin= total revenue - total variable cost

= ₦2950 – ₦2700

= ₦250

Net profit = total revenue– total cost

= ₦2950– ₦3650

= (₦-700)

Rate of return on investment

$$= \frac{\text{Net profit of investment}}{\text{Total cost on investment}} \times 100$$

$$= \frac{(-700)}{3650} \times 100$$

= (-0.19)

=-19%

The total revenue generated, the total fixed cost and variable cost from the control cucumber production in the study area gives a gross margin of ₦250 and a net profit of ₦-700. The rate of return of 19% implies that, for every ₦1 spent on organic cucumber farming, a loss of (19) Kobo/0.0075ha was realized. This indicated that control cucumber farming system was not profitable in the study area. This implies that the cultivation of cucumber without the addition of fertilizers (organic or non-organic) leads to a loss.

Comparatively, it was discovered that the organic farming system incurred the highest cost of production, compared to that of non-organic system. The non-organic farming system was found to yield the highest rate of return, followed by the organic system. This is in accordance with the findings of Offermann and Nieberg, (2000) that yields in organic farms are most often lower than non-organic farms, to varying degrees. Also, Alawode & Abegunde, (2015) found that non-organic farming system had higher rate of return compared to other crops cultivated under organic farming systems; lower rate of return on organic farming system to non-organic system can also be due to the fact that rate of return is lesser in the first season of production which may be due to high variable cost which may elongate payback period in the first production season.

Table 3: Profitability analysis of cucumber production in ₦/season

Cost items	Organic (₦)	Non-organic (₦)	Control (₦)	All (₦)
Variable costs				
Cost of seed	1,300.00	1300	1300	3900
Cost of labour	700	700	600	2000
Cost of manure	1000			1000
Cost of fertilizer (NPK)		400		400
Cost of fertilizer (Urea)		450		450
Non-organic pesticide		700		700
Organic pesticide	1000			1000
Cost of transportation	700	700	600	2000
Miscellaneous	400	400	200	1000
Total Variable Cost (TVC)	5100	4650	2700	12450
Total Fixed Cost (Depreciated)	1050	1000	950	3000
Total Cost (TC)	6150	5650	3650	15450
Return				
Total revenue	9750	9220	2950	21920
Gross margin (TR - TVC)	4650	4570	250	9470
Net profit (GM - TFC)	3600	3570	-700	6470
Rate of return (NP/TC)	0.59	0.63	-0.19	0.42

Source: Field experiment Data, 2019

CONCLUSION AND RECOMMENDATIONS

Profitability depends on soil type, management practices, availability of market, labour availability, agronomic factors, etc.It can therefore be concluded that, the organic system of production produced higher growth and yield than the non-organic system. Based on the rate of return on investment non-organic shows a higher rate of return compared to the organic system which may be due to high variable cost incurred in production, while the control system run at a loss. Based on the results of this research, the study therefore, recommend the followings:

i. Farmers should cultivate cucumber using other organic based phosphorus fertilizers which will aid fruit formation in cucumber for a higher rate of return;

ii. There should be an intensified awareness by extension agents and government to improve the level of participation of farmers in organic farming through extension agents, media, publications, seminars etc where non-organic farming is unaffordable.

iii. Farmers should adopt good production and management practices such as crop rotation, cover cropping, etc., to enhance their productivity either organic and non -organic so as to increase their profitability margin.

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PROFITABILITY AND RESOURCE-USE EFFICIENCY OF SMALL-SCALE AMARANTH (*Amaranthus cruentus*) PRODUCTION IN KEFFI AREA OF NASARAWA STATE, NIGERIA

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ABSTRACT

Amaranth is one of the most important vegetable plants consumed in Nigeria. However, due to inadequate basic knowledge about resource combination, amaranth output is poor. This study determined the efficiency of amaranth production among small scale farmers in Keffi Local Government Area of Nasarawa State, Nigeria. A multi-stage random sampling technique was used to select 60 respondents for the study. Data generated were analyzed using descriptive, production function analysis, and gross margin analysis. The results of the costs and returns analysis revealed a Gross Margin (GM) of ₦26, 934.77. Return on Naira Invested (ROI) by respondents engaged in amaranth farming was N2.43. The results of the marginal value productivity (MVP) and efficiency of resource use in amaranth farming revealed that labour, agrochemicals farm size and fertilizer were over-utilized while seed was under-utilized in the production of amaranth. The major constraints militating against amaranth production in the study area revealed that the most prominent constraints in order of severity were inadequate fund (93.3%), poor pricing of amaranth (85.0%), absence of storage facilities (80.0%), and poor extension visit (73.3%). The study recommended that policy measures on efficient use of production inputs by the amaranth farmers should be directed towards making technology available and farmers' training through the extension agents to improve their resource use.

Keywords: Profitability, resource-use, efficiency, small-scale, amaranth

INTRODUCTION

Agricultural development is one of the most effective weapons for eradicating extreme poverty, increasing shared prosperity, and feeding a projected 9.7 billion people by 2050 (World Bank, 2023). Nigerian agriculture still maintains peasant-oriented economy that was prominent in the pre-independence period. Small scale farming constitutes the nucleus of Nigerian agriculture, producing about ninety percent of food and fibre for the Nigerian Population. In addition, it offers employment to about eighty percent of the population, provides food, source of foreign exchange, and contribution to the country's GDP (Adewunmi and Omotesho, 2020). Vegetable growing is the most important branch of horticulture in view of the value of its products. About 89 percent of the total production of vegetable is taken in fresh stage while remaining 11 percent is processed. Nigeria is abundantly blessed with many varieties of local and some foreign vegetables, which are included in business (Olujide and Oladele, 2019). Generally, the production of vegetable is an important component of the farming systems of the northern states of Nigeria using irrigation. This is because it is a very lucrative economic activity due to the availability of markets in the vicinity of the production areas and in the southern states where there is high demand for them (Ibrahim and Omotesho, 2020). Some of these vegetables include Lettuce, Amaranth, Cucumber, Watermelon, Carrot, Cabbage, Cauliflower and Okra (Ibrahim and Omotesho, 2020).

Amaranth (*Amaranthus cruentus*) is a leafy vegetable produced in almost all the states in Nigeria, especially in the rural and peri-urban centres of the country (Ojo *et al.,* 2011 and Owombo *et al.,* 2012). Amaranthus has also been regarded as relatively drought tolerant, thus, suggesting that reasonable yield can be realized with limited irrigation. It is grown as mono crop or intercropped with other staple food crops in traditional farming systems for family consumption and market. Apart from its uses as a vegetable, it has also been used as an effective alternative to drug therapy in people with hypertension and cardiovascular disease (CVD) (Martiorosyan and Miroshnichen, 2017). The demand for this crop as vegetable has increased, especially in the urban centres where people are not involved in primary production (Schippers, 2010). This has made the vegetable to become an important commodity in our market and also an important economic activity for the rural farmers.

The amaranth leaves are cooked alone or combined with other local vegetables such as pumpkin. The leaves are rich in calcium phosphorus, folic acid, potassium, iron and vitamins A, B and C but fairly low in carbohydrate (AVRDC, 2013; Okpara *et al.*, 2014). The crop is commonly used as leafy vegetable and is a cheap vegetable for the common man (Fayemi, 2015). Amaranths are recommended as a good food with medicinal properties for pregnant women, children lactating mothers and patients with constipation, fever, haemorrhage and anaemia (Quinton, 2016). It was reported to contain twice the amount of calcium that fresh milk contains per unit of serving. It enhances mental hormones and helps lower cholesterol levels significantly in the blood (AVRDC, 2013). Among several uses of amaranth include: grains used in breakfast cereals or as an ingredient in confectioneries; South Americans parch or cook it for gruel of porridge, or mill it to produce light-colored flour. As a snack, the tiny grains are popped and taste like nutty-flavored popcorn, or it is mixed with honey. The leaves (which are high in protein, vitamins and minerals) are boiled and eaten as greens. They are the most commonly grown vegetable of the lowland tropics in Asia and Africa (Costea *et al.*, 2016).

The yield per hectare of amaranths in Nigeria is low (7.60 ton per hectare) when compared to that of United States (77.27 ton per hectare) and world average (14.27 ton per hectare) (FAO, 2017). For commercial production, optimum performance of the crop must be desirable through changes in cultural practices (sterrett and Savage, 2012). Such cultural practices include higher planting density and application of organic manures and fertilizer for improving growth and yield of the crop. Fertilizer application is the quickest and easiest ways of increasing crop productivity. The crop Amaranthus species is an important leafy vegetable of high dietary value and widely consumed in Nigeria. Grain amaranth's balanced amino acid composition is close to the optimum protein reference pattern in human diet according to FAO/WHO requirements (Mlakar *et al.,* 2010). It is also an important crop in rain-fed and irrigated vegetable production systems of small-scale farmers around urban areas and population centres in the country (Ojo *et al.*, 2011). *Amaranthus spp*. is one of the most important leafy vegetables widely grown in the tropics with a potential to broaden man's food base in Africa (Neluheni *et al.*, 2015).

Nigeria, the most populous country in Africa about 175 million (Mustapha *et al.*, 2013) is essentially agrarian in nature with over 80 percent of her food needs being produced by peasant farmers, cultivating in most cases less than 2 hectares of land (Adeoye *et al.*, 2011). Amaranth is one of the essential vegetable plants consumed in the Northern Nigeria under subsistence method of farming. In Northern Nigeria, Amaranths output is drastically low because farmers do not have adequate knowledge of resource combination (Okpara *et al.*, 2014). The resource available at their disposal is even not well allocated which tantamount to low production. Empirical studies suggest that most developing countries are still facing the problem of high poverty level.

In addition to poverty, Nigerian population growth rate is very high; yet agricultural resources are limited, e.g. arable land. This calls for improving yields of essential vegetables, such as amaranths for better food security and livelihoods of rural households. Thus, resources need to be used in the most efficient way to achieve this objective. Further, improved efficiency is expected to improve food security by cutting hunger halfway by 2025 (Okoye *et al.*, 2018). Most farmers in Nigeria practice subsistence farming with low productivity. This may be attributed to high inefficiencies because farmers lack access to available resources or less information on efficiency, and low literacy levels limiting interpretation of such information to guide them in commercial production and efficient utilization of resources which lead to improve production in the study area. Based on the foregoing, it is relevant to provide answers to the following research questions. Among the many research work done on resource utilization of arable crops, there is dearth of information on resource-use efficiency of small scale amaranths producers. There is therefore the need to determine the resource use efficiency of the amaranths farmers in the study area. Resource use measurement is very important because it is the first step in a process that might lead to substantial resource savings.

The main objective of this research work is to investigate the profitability and efficiency of amaranths production among small scale farmers in Keffi Local Government Area of Nasarawa State, Nigeria. The Specific objectives are to;

i. estimate the costs and returns in amaranths production in the study area;
ii. estimate the relationship between input and output in amaranths production in the study area;
iii. determine the resource-use efficiency in amaranths production in the study area; and
iv. identify the constraints militating against amaranths production in the study area.

Hypothesis

Ho: Small-scale amaranth producers in the study area are not efficient in using resources for production.

Empirical Review

Obalola and Tanko (2016) examined the comparative economic analysis of irrigated and rainfed spinach (*Amaranthus cruentus*) production in Minna metropolis, Niger State, Nigeria. Data were obtained from 120 randomly selected farmers using the purposive sampling technique. Production function model was used in the analysis of the data. The result showed that labour and farm size are the significant variables that influence spinach production output under the rainfed condition. On the irrigated scenario, labour, quantity of organic manure and quantity of improved seeds were the variables that influence the output of spinach production. It also revealed that there was over utilization of all the production inputs (i.e. labour, farm size, quantity of organic manure and the quantity of improved seeds) under consideration. Incorporating policy measures of efficient use of production inputs was suggested.

Gbigbi, *et al.* (2011) identifies and analyzes factors that influence the resource use of smallholder amaranths producers in Delta State by drawing on data from random sample of 60 smallholder farmers from Ughelli South Local Government Area. The study employed stochastic frontier and Tobit model to measure the level of economic efficiency and its determinants in amaranths production. Empirical results show decreasing returns to scale in production. The mean economic efficiency is 0.61 with a range of 0.13 to 0.99. Education, access to extension, access to credit and membership of farmer's cooperative positively and significantly influence economic efficiency. Innovative institutional arrangements that enhance extension and farmer training accompanied with improved access to credit is likely to enhance amaranths production efficiency.

Ogundari *et al.* (2016) examine the overall resource use and efficiency of small holder amaranths producers in Nigeria with a view to examine the productive efficiency of vegetable production in the country. Data were collected from 200 farmers selected using multi-stage sampling technique and analyzed using descriptive statistics, stochastic frontier production and cost function models. The return to scale (RTS) for the production function revealed that the farmers operated in the irrational zone (stage I) of the production surface having return to scale (RTS) of 1.113. The mean technical, allocative and economic efficiency of 0.733, 0.872 and 0.684 respectively were obtained from the data analysis, indicating that the sample farmers were relatively very efficient in allocating their limited resources with allocative efficiency (AE) appears to be more significant than technical efficiency (TE) as a source of gains in economic efficiency (EE). The result of the analysis indicate that presence of technical inefficiency and allocative inefficiency had effects in the vegetable production as depicted by the significant estimated gamma coefficient of each model, the generalized likelihood ratio test and the predicted technical and allocative efficiencies within the farmers.

METHODOLOGY

The Study Area

The study was conducted in Keffi Local Government Area of Nasarawa State, Nigeria. The choice of the study location was guided by the volume of amaranths production. It lies between latitude $7^0$00'and $9^0$00'North and longitude $7^0$00'and $10^0$00'East. The area has a mean temperature ranging between 25^0C in October to about 36^0C in March, with mean annual rainfall of about 1500mm. Keffi Local Government Area has a land area of about 138km^2 and a population of about 92,664 at the 2006 population (NPC, 2006). The major occupation of the population of the area is farming and the dominant tribes are

Hausa/Fulani, Gwandara, Gbagyi, Nyankpa (Yeskwa) and Afo. Keffi has one extension block with six cells namely; AngwanJaba, Bagaji, Gauta, Keffi, KafinShanu and Yarkadde.

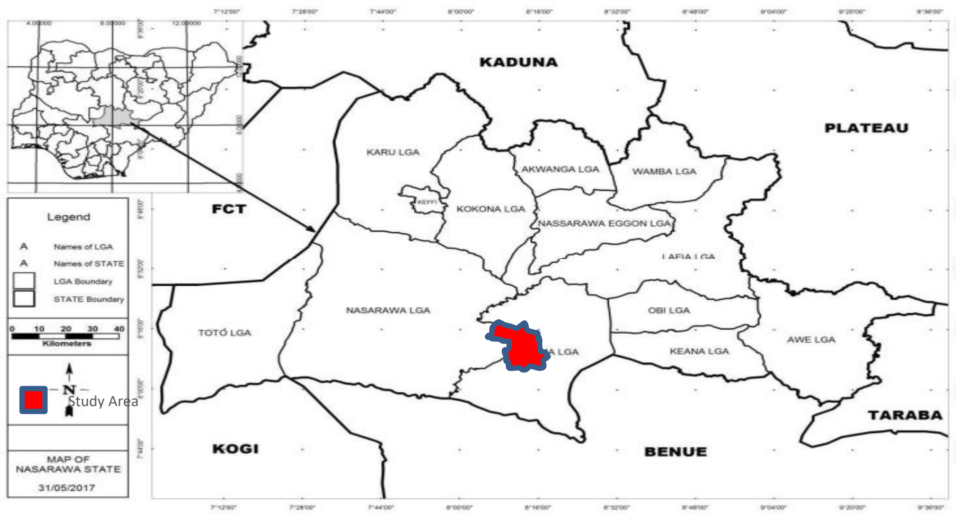

Figure 1: Map of Nasarawa State Showing the Study Area (Source: NAGIS, 2017)

Sampling Technique and Sample Size

A multi-stage random sampling technique was used for this study. The first stage involves a purposive selection of three (3) cells out of the six cells (Bagaji, Gauta, and Keffi) in Keffi Local Government Area. This was due to the predominant production amaranths from these cells. In the second stage, four (4) villages were randomly selected from the selected cells to give 12 villages. In the third stage, five (5) farming households involved in amaranths production was randomly selected. This gives a total of 60 respondents that was used for the study.

Data Collection

The data for this study was collected from primary source only. The data was obtained using the interview method with a structured questionnaire that was administered among the respondents. Questions were asked on the socioeconomic characteristics, inputs and output used in amaranths production, and constraints faced by amaranths producers.

Method of Data Analysis

The tools that were used to analyze data include; descriptive statistics (mean, frequency and percentages), Stochastic Frontier Production and Budgetary analysis.

Cobb-Douglas

The Cobb-Douglas model estimate (double log) comprises both efficiency parameter and inefficiency parameter and this was used to achieve objective ii. The model is explicitly specified as;

$$\ln Y_i = \beta o + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 - (U_i)$$

Where Y= Revenue from amaranths (kg)

$\beta 0$ = Constant estimate for efficiency model

X_1- X_5 =Efficiency parameters

X_1 = Farm size cultivated (ha)

X_2 = Labour (man days)

X_3 = planting material (kg)

X_4 = quantity of agrochemicals (in litres)

X_5 = quantity of fertilizer (kg)

Efficiency of resource used was determined by the ratio of Marginal Value Product (MVP) to Marginal Factor Cost (MFC) of inputs based on the estimated coefficients. Following Rahman and Lawal (2003) and Iheanacho *et al.* (2000) efficiency of resource (r), is given as:

r= MVP/MFC………………………… (3)

Thus, r = 1; indicates efficient use of a resource; r > 1; indicates underutilization of a resource; and r < 1; shows over utilization of a resource.

Therefore, MVP and MFC will be estimated as follows:

MVP = MPP.P_y = β_i Y/X.P_y……………………………………..(4)

Where:
MFC = P_{ij} ;
MFC = Marginal Factor Cost;
r = xi Efficiency ratio;
P_{ij} = (unit price of input X);
MPP = xi i Marginal physical product;
MVP = Marginal Value Product;
β = Regression coefficient;
Y = Mean output of farm;
X = Mean value of resource;
P_y = Unit price of output

Budgetary Analysis

The farm budgetary technique will be used to analyze objective iii of this study. As used by Olukosi and Erhabor (2008), the gross margin is the difference between gross farm income and the total variable cost of production. It will be used in this study to estimate the profitability level of sweet potatoes production in the area. This tool was used because in subsistence farming the fixed cost is assumed to be negligible (Olukosi and Erhabor 2008). The model is specified as:

GM = G1 – TVC ----------------------------- (1)
NFI = GM – TFC ……............................ (2)
Where,
GM = Gross margin per hectare (₦)
GI = Gross income per hectare (₦)
TVC = Total variable costs per hectare (₦)
NFI = Net farm income per hectare (₦)
TFC = Total fixed costs per hectare (₦)

RESULTS AND DISCUSSION

Socio-economic characteristics of the Respondents in the study area

From Table 1, the mean age of the respondents was 32 years implying that most of the respondents were in their productive active age suitable for amaranth production. Ogumbameru (2001) asserted that young and middle-aged people are the most active in agricultural production activities for increased productivity. Majority (73%) of the amaranths farmers in the study area were male. The mean farm size was observed to be 3.0 hectares. Majority (85%) of the amaranth producers in the study area had basic education and therefore are able to read, write and comprehend basic instructions, so if they are visited by extension agents had access to extension services, they can comprehend and adopt innovations that will enable them to participate better in amaranths production activities. Formal education enables a farmer to seek for and utilize useful information from both print and electronic media. Education accelerates the rate of adoption of farm technologies (Ozor and Madukwe, 2005 and Agbamu, 2014).
Furthermore, the mean household size was 6 persons per household. The mean years of experience was 9 years. This implies that amaranths farmers in the study area were relatively experienced in the business and may possess relevant skills in the management of amaranths production enterprise. Experience

is important for effective day-to-day running of farm enterprise and could influence positively the adoption of innovations (Adebiyi, 2008). Majority (70%) of the amarantus producers belong to one cooperative group or the other. Ibrahim *et al.* (2007) stated that belonging to a cooperative society enhance farmers productivity through farm inputs acquisition and distribution. Majority (62%) of the respondents had no access to extension services in the study area while only 38.3% had access to extension services. This shows an inadequate extension visit in the study area. The relationship between agricultural extension agent and the farmer is an important determinant in improving yield, income of the farmers as well as in ensuring food security (Chikezie *et al*., 2012).

Table 1: Socio-economic characteristics of the respondents

Characteristics	Frequency	Percentage	Mean ($\bar{X}$)
Age			
1-20	6	10.0	
21-40	38	63.3	
41-60	13	21.7	32
Above 60	3	5.0	
Total	60	100.0	
Sex			
Female	16	26.7	
Male	44	73.3	
Total	60	100.0	
Farm size			
1-2	32	53.3	
3-4	21	35.0	3.0
Above 4	7	11.7	
Total	60	100.0	
Marital status			
Married	45	75.0	
Single	15	25.0	
Total	60	100.0	
Educational status			
Primary education	20	33.3	
Secondary education	31	51.7	
Tertiary education	9	15.0	
Total	60	100.0	
Household size			
1-5	33	55.0	
6-10	20	33.3	6.0
Above 10	7	11.7	
Total	60	100.0	
Farming experience			
1-5	16	26.7	
6-10	22	36.7	
11-15	19	31.7	9.0
16-20	2	3.3	
Above 20	1	1.7	
Total	60	100.0	
Cooperative membership			
No	42	70.0	
Yes	18	30.0	
Total	60	100.0	
Extension visit			
No	37	61.7	
Yes	23	38.3	
Total	60	100.0	

Source: Field survey, 2021

Costs and returns in amaranths production in the study area

The results of the costs and returns analysis as presented in Table 2 revealed that, the total variable cost per hectare of amaranths production was N14,465.23 which represents 85.0% of the total cost of production. The total cost of production of amaranths per hectare was N17,019.93. The total revenue (TR), Gross Margin (GM), Total variable cost (TVC), and Return on Naira Invested (ROI) by respondents engaged in amaranths farming was: ₦41,400, N26,934.77, ₦14,465.23 and ₦2.43 respectively. The value of the gross margin obtained from the study indicated that amaranths production is an essential income earner for the farmer in the study area. Also, it was also observed that for every naira invested, a profit of ₦1.43 was realized. Information from the profitability analysis shows that amaranths farming is a viable business in the study area with a profit margin of ₦14,465.23 per hectare. Though it could be more profitable if managed properly with adequate records. These results implied that amaranths production is a profitable business. The implication of this result is that considering the economic situation of the country, people can take an advantage of this venture and produce amaranths as a means of livelihood. This also corroborates Shu'aib *et al.* (2017) who in their study of the profitability analysis of vegetable amaranth (*Amaranthus cruentus*) production along metropolitan *Jakara* River in Kano, Nigeria reported that amaranths production was a profitable venture.

Relationship between Output and Inputs used in Amarantus Production

The results of the Cobb-Douglas regression analysis as presented in Table 3 revealed that the value of the co-efficient of determination (R^2) was 0. 560. This implies that the regression results indicate that about 66% of the variation in the revenue of amaranths is jointly explained by the explanatory variables included in the model. Thus, the regression has a good fit to explain the relationship of income and inputs involved in amaranths farming. The F-ratio, 13.748 is statistically significant at 1 % which indicates that the explanatory variables adequately explained the model. The most significant variables influencing the income of the farmers were agrochemical (p =0.05), and seed (p =0.001). Also, seed was negatively correlated to the respondents' revenue. This implies that increasing the use of seed will lead to a decrease in respondents' revenue. Additionally, agrochemical was positively correlated to the respondents' revenue, implying that increasing its usage will lead to increase in respondents' revenue in the study area. This result is in tandem with Obalola and Tanko (2016) who in their study of the Comparative Economic Analysis of Irrigated and Rainfed Spinach (A*maranthus cruentus) Production* in Minna Metropolis, Niger State, Nigeria observed that seed and planting materials were significant in influencing farmers profits.

Resources used in Amaranths Production in the Study Area

The results presented in Table 4 show the marginal value productivity and efficiency of resource use in amaranths farming in the study area. Labour, seed, farm size, and fertilizer were over-utilized, while agrochemical was under-utilized in the production of amaranths. The over-utilization of labour could be attributed to the use of labour-intensive technologies as against the use of labour-saving devices such as the tractor (Saito *et al.*, 1994; Ogungbile *et al.*,1999). This result agrees with that of Obasi *et al.* (2013) who, in their work on factors affecting agricultural productivity among arable crop farmers in Imo State of Nigeria found that labour was over-utilized with an efficiency ratio of 0.086. The over-utilization of fertilizer and seed could be linked to subsidies on these inputs and to the fact that majority of the farmers (61.7%) had no contact with extension personnel who can properly educate them on the recommended rates of application of fertilizer and seed rate to apply on their farm land. This result of over-utilization of fertilizer agrees with that of Adeyemo *et al.* (2010) who in their work on economic efficiency of small-scale farmers in Ogun State of Nigeria found that fertilizer was over-utilized with an efficiency ratio of -0.152. The result of over-utilization of seed agrees with that of Ogunniyi *et al*. (2012) who, in their work on resource-use efficiency in vegetable production in Atakunmosa Local Government Area of Osun State found that seeds were over-utilized with an efficiency ratio of 0.034.

The reason for the under-utilization of agrochemical could be attributed to the inadequate knowledge of the respondents on the recommended quantity of agrochemical to apply per hectare. It could also mean that the respondents may not be using the agrochemical at the appropriate time needed to subdue weed and insect attack on their farm. The over-utilization of farm size could be attributed to the fact that farmland was acquired mainly by inheritance in the study have been subjected to long time production processes, hence making it to lost it fertility. These results are consistent with those of Ogunniyi *et al*. (2012) in their work on resource-use efficiency of vegetable production in Atakunmosa Local Government Area of Osun State of Nigeria where farm size and planting material were found to have been over-utilized and under-utilized with efficiency ratios of 0.043 and 3.528, respectively. It can be concluded that as a whole, that amaranths farmers in the study area were still at the stage I level of production and that all the resources were not efficiently utilized in the study area.

Constraints militating against amaranths production in the study area

Table 5 shows the major constraints militating against amaranths production in the study area. It was revealed that the most prominent constraints in order of severity were inadequate fund (93.3%), poor pricing of amaranths (85.0%), absence of storage facilities (80.0%), and poor extension visit (73.3%). This indicates that majority of the amaranths farmers in the study area faced a majo challenges ranging from inadequate fund, poor pricing and poor storage facilities as amaranths is easily perishable. This is in line with Onuk *et al.* (2017) who studied the Economic Analysis of Dry Season Vegetable Farming Among Women in Makurdi Local Government Area of Benue State, Nigeria observed that vegetable farmers were constrained by inadequate finance, among others.

Table 2: costs and returns in amaranths production in the study area

Cost and Return Items	Mean Value (₦ /ha)	Percentages of Variable Cost
Total Revenue (TR) (Naira)	41,400	
Variable Cost (Naira)		
Fertilizer	7,318.33	50.6
Agrochemical	5,465.00	37.8
Labour	579.4	4.0
Seed	710.83	4.9
Transport	391.67	2.7
Total Variable Cost (TVC)	14,465.23	
Fixed Cost (FC) (Naira)		
Land	2,554.70	
Total Cost (TC) (Naira) (FC+TVC)	17,019.93	
Net Return (NR) = TR-TC	24,380.07	
Gross Margin (GM) = TR-TVC	26,934.77	
Return Per Naira Invested	2.43	

Source: Field survey, 2021

Table 3: relationship between output and inputs used in amarantus production

Variable	Coefficient	Std. Error	t-value	Sig.
(Constant)	-1.799	0.580	-3.103	0.003
Labour	0.008	0.087	.091	0.928^{NS}
Seed	-0.046	0.018	-2.603	0.012**
Agrochemical	0.436	0.062	6.996	0.000***
Farm size	-0.010	0.096	-0.102	0.919^{NS}
Fertilizer	0.057	0.053	1.065	0.291^{NS}

Source: Field survey, 2021
R^2 = 0. 560
F-value = 13.748 (p = 0.000)
***significant at 1%
**significant at 5%
NS = Not Significant

Table 4: Resources used in Amaranths Production in the Study Area

Resources	Bi	MPP = bi.$\bar{Y}/\bar{x}$	Py(₦)	MVP (₦)	MFC(₦)	r = MVP/MFC	Decision
Labour	0.008	0.0028	50	0.14.0	1300	0.00011	Over utilization
Seed	-0.046	-6.57	50	-328.5	60	-5.475	Over utilization
Agrochemical	0.436	38.76	50	1938.0	1200	1.6125	Under utilization
Farm size	-0.010	-0.74	50	-37.0	700	-0.053	Over utilization
Fertilizer	0.057	6.71	50	335.5	380	0.874	Over utilization

Source: Field survey, 2021

Table 5: Constraints Militating against Amaranths Production in the Study Area

Constraints	Frequency	Percentage	Rank
Inadequate fund	56	93.3	1st
Poor pricing of Amaranths	51	85.0	2nd
Absence of storage facilities	48	80.0	3rd
Absence of extension services	44	73.3	4th
High cost of farm inputs	34	56.7	5th
Problem of erosion	19	31.	6th

Source: Field survey, 2021

CONCLUSION

Amaranth production is a profitable enterprise in the study area as indicated by the values of gross margin and return on Naira invested. However, all the resources used in the production of amaranths in the study area were inefficiently utilized. The major constraints to amaranths production in the study area include inadequate fund, poor pricing of amaranths, and inadequate storage facilities. Based on the findings, policies measures and good agricultural practices by farmers are therefore recommended for improved resource use and profit.

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SOIL SCIENCE AND CROP PRODUCTION

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AGRONOMIC EVALUATION OF NEEM BASED ORGANIC FERTILIZER ON GROWTH AND YIELD OF CASSAVA GROWN ON SOILS OF SHALE PARENT MATERIAL IN SOUTHEASTERN NIGERIA

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ABSTRACT

Studies were conducted to investigate the effect of neem based organic fertilizer on the on growth and yield of cassava grown on soils derived from Shale parent material at the National Root Crops Research Institute Igbariam Sub-Station Anambra State experimental field, during the 2017/2018 and 2018/2019 wet cropping seasons. Prior to trial establishment soil samples from the experimental sites were collected at 0 to 20 cm depth and analyzed in Soil Science Laboratory alongside the neem based fertilizer. Result revealed that the soil was moderately acidic (pH 5.5), had moderate total N (0.16 %), moderate available P (10.50 $mgkg^{-1}$), low exchangeable K (0.18 $cmolkg^{-1}$), moderate organic Carbon (2.50 %) and Sandy clay loam texture. The neem fertilizer contains 3 % N, 6 % P, 3 % K and 30% organic Carbon by composition. Based on the nutrient requirement of cassava and the analytical result, 6 treatment combinations were made and applied 8 weeks after planting of cassava (TME 419) and the experimental design was randomized complete block design replicated three times. The yield result showed that neem based fertilizer and N P K fertilizer mixture at the rate of 2,250 kg neem and 187.5 kg N P K 12: 12: 17 + 2 gave significantly ($P < 0.05$) higher fresh root yield in both years than any other treatment, and is therefore recommended for sustainable cassava production in the soils studied.

Keywords: cassava, evaluation, organic fertilizer, parent material, yield and shale

INTRODUCTION

Cassava is an important stable crop in Nigeria but more and more used as cash and industrial crop, contributing to economic development. Nigeria is the largest producer of cassava in the world with about 60 million metric tons (FAOSTAT, 2020) annually. Cassava contributes greatly to food security and as raw material for industrial processing. It provides the livelihood (food and income) for over 30 million farmers and countless processors and traders in Nigeria (Abdulaye *et al.*, 2014). Cassava chips are effective substitute for cereals in pig and poultry diets, while cassava starch is high quality resource for paper and textile industries (FAO, 2018). It is also used as feedstock for ethanol production (Adejuwon, 2006). It has been observed that Nigeria is the most advanced among the African countries poised to diversify the use of cassava as primary industrial raw material and livestock feed. According to Solomon *et al.*, (2011) two factors are responsible for this comparative advantage and they include rapid adoption of improved cassava varieties and the development of small scale processing technologies.

Increasing demand for cassava offers farmers the opportunity to intensify production, earn higher income and boast their food supply (Howler *et al*., 2012). This can be achieved through soil fertility improvement to enhance cassava root yield. According to Onyekwere *et al*., (2020) the global rating of Nigeria as number one producer of cassava is not as a result of yield per unit area of land. Its yield in farmers field is (below 9 tons per hectare), but as a result of large expanse of land subjected to its production in the country. According to FAO, (2017) total area of land under cassava cultivation in Nigeria is 6.9 million ha representing about 26.54 % of the entire global land area subjected to cassava production. The low root yield being recorded can be attributed to inherent low fertility of the tropical soils, which can be improved through fallowing. Currently, due to population increase and rural urban industrialization, the available piece of land meant for cassava production had diminished and fallow period reduced and land expansion to tackle the global food need of the rising population is not possible. Base on this the available agricultural land is subjected to continuous cropping. Therefore, for yield increase to be feasible and to sustain productivity of cassava in Nigeria soil fertility need to be improved upon. It should be noted that generally tropical soils has inherent low fertility. Most Nigeria soils are highly susceptible to degradation as a result of leaching, low soil reaction (pH), low organic matter content and exchange cations. Ojeniyi and Adejobi (2002). This has compelled farmers to amend the soil with different fertilizer (Organic and in-organic) in other to enhance plant growth and increase soil productivity

It has been observed that the use of organic materials as soil amendment, improves environmental condition, public health as well as the quality of the crop. The fertility status of the soil is also improved by the activities of soil micro- organisms.

In addtion, Abuo El-magd *et al*., (2006) reported that the application of organic manure plays a role in plant growth and also as source of all essential macro and micro nutrients in available forms during mineralization, thereby improving both physical and biological properties of the soil.. Therefore,. The objective of this study was to determine the effectiveness and the optimum rate of neem based organic fertilizer for performance and fresh root yield of cassava grown on soils derived from shale parent material in southeastern Nigeria.

MATERIALS AND METHODS

Study Area

The experiments were conducted at the Igbariam sub station, Anambra State of the National Root Crops Research Institute (NRCRI), Umudike, south east geo-political zone of Nigeria. The study area is located within latitude 6.302165^{o}N and longitude 6.966104^{o} E. The climate of the area is characterized by distinct wet and dry season, while the wet season last for about seven months and starts immensely from April to October. The dry season stretches mainly from March through November. It can be remarked that a condition of great climatic uniformity is experienced in the area throughout the year. The area has a mean annual temperature between 22 and 32^{0}C,the mean annual rainfall range from2,490 to 2,900mm and the relative humidity vary from 60 to 74% (Table 1). The vegetation of the study area consist of derived savannah .The prevailing condition in the study area has compelled people towards adapting integrated livestock crop and integrated tuber/root crops/maize/egusi farming systems that are comparatively at advantage and can adapt to their environment. The soil of the study area is derived from shale parent material.

Table 1: Ten years (2009-2018) meteorological data of the studied area

Year	Temperature (^{o}C)		Rainfall (mm)		Relative humidity (%)		Sunshine Hours
	Minimum	Maximum	Days	Amount	1500	900	
2009	23.50	31. 80	155	2600.10	60	70	4.9
2010	24.00	32.00	144	2650.50	62	71	4.7
2011	22. 30	32.30	142	2780.80	61	72	4.5
2012	22.00	31.70	146	2850.80	60	72	4.8
2013	22.30	32.00	138	2750.40	62	74	4.6
2014	22.30	31.60	130	2490.00	63	71	4.5
2015	23.40	31.80	150	2690.90	60	71	4.7
2016	23.30	32.00	141	2800.00	61	70	4.7
2017	22.60	31.90	142	2900.00	62	72	4.8
2018	22.00	31.70	150	2890.50	61	74	4.6
Totals	227.7	221	989	2000.30	426	498	32.6
Mean	22.77	31.88	129.20	2740.40	61.20	71.70	4.68

Source: NRCRI, Igbariam Sub-Station Metrological Unit, 2019

Sampling Scheme and Laboratory Analysis

Prior to land preparation 10 pre-planting soil samples were collected in W shape form in the experimental site using soil auger at the 0-20cm depth and mined into a composite sample in each cropping season, labeled and then transported to the Soil Science Laboratory of the National Root Crops Research Institute (NRCRI), Umudike, Abia State for physical and chemical analysis. The soil samples were air dried, crushed and sieved through a 2 mm mesh and re-sieved through a 0.5 mm mesh for organic carbon and total N prior to physical and chemical analysis. The samples were then analysed using standard laboratory methods.

Physical Properties

Soil particle size analysis was determined after dispersing 51.00 g of air – dried soil samples with 5 % sodium hexametaphosphate overnight that is the Boyoucous hydrometer method, as contained in the method of soil analysis by International Soil Reference and Information Center and Food and Agricultural Organization. (ISRIC and FAO, 2002).

Chemical Properties

The chemical properties of the soils were determined according to standard laboratory procedures as contained in the method of soil analysis by International Soil Reference and Information Center and Food and Agricultural Organization. (ISRIC and FAO, 2002).

Soil pH (H_2O) was determined in 1:1 soil/ distilled water suspensions using a glass electrode. Organic carbon was determined by Walkley and Black titration method, which involved soil organic matter oxidation with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4). Total nitrogen was determined by using the modified Macro - Kjeldahl method. of digestion, distillation and titration. Available phosphorus was determined using Bray P -2 extract of Bray and Kurtz method, and measured calorimetrically. Exchangeable Ca, Mg, K and Na in soil samples were extracted with I N neutral ammonia acetate (NH_4OAc), K and Na were determined by flame photometry while Ca and Mg were by EDTA titration.The soil samples were treated with I N KCl to extract the exchangeable H^+ and Al^{3+}. The KCL extract was subsequently titrated with 0.05 N NaOH. The amount of base used was equivalent to the total acidity. Exchangeable bases were extracted using 1N potassium acetate (KOAc) saturation and neutral IN (NH_4OAC) displacement using 5 g of soil sample. The displaced potassium was determined on a flame photometer thus CEC was estimated as follows:

$$\frac{\text{CEC cmol (+)kg}^{-1}}{\text{100g soil}} = \frac{\text{cmol (+)kg}^{-1}\text{ k}}{\text{100g soil}}$$

Effective cation exchange capacity was calculated as the sum of the exchangeable bases and acidity. Percentage Base Saturation was calculated as the percentage of exchangeable bases divided by effective cation exchangeable capacity.

$$\frac{(K^1 + Na^1 + Ca^2 + Mg^2)}{\text{ECEC}} \times 100$$

Agronomic Practices

The trial was established during the 2017/2018 and 2018/2019 wet cropping seasons. The fields were fallowed for two years in each season, after which they were slashed ploughed harrowed and ridged and planted cassava stakes measuring 20 to 25 cm on the crest of the ridges in slanting position of about 45 degrees, laid out in 6 m x 6 m plot size with a planting space of 1mx 1m, and the variety of cassava planted was an erect type known as UMUCASS 20 (TME 419), a very popular cassava variety among the Nigeria cassava farmers. the nutrient composition of neem based organic fertilizer and the soil analytical result of the experimental sits. The available inorganic fertilizer used in the composition was NPK 12 :12:17 + 2 Mg. The plots were weeded 6 and 20 WAP then under brushed 32 WAP. Data were collected on plant height, girth size, number of leaves and fresh root (t/ha) yield harvested 12 MAP

Experimental Design

The experimental design was Randomized Complete Block Design (RCBD) replicated three times, with six treatments that were applied 8 Weeks After Planting (WAP). These treatments were composed based on the nutrient requirement for cassava production.

Data Analysis

Data were analyzed statistically using SAS (2004) computer package and means were separated using LSD at 5 % probability.

RESULTS AND DISCUSSION

Soil and Neem Composition

The mean values of the physical and chemical properties of soils of the experimental sites for the two cropping seasons (2017/2018 and 2018/2019) studied is presented in Table 3

Soil Physical Properties

Particle Size Distribution

The sand fraction of the soil studied was 684.0 gkg^{-1}, the silt content was 108.0 gkg^{-1} while the clay content was 208.0 gkg^{-1} (Table 3)

Textual Classification

The textual classification of the soil was sandy clay loam. (Table 3) Generally the textual classification of this soil agrees with optimum criterion of light medium loams, sandy soils required for unhindered anchorage and bulking of roots and tubers and for easy harvest including cassava. (Onyekwere *et al.*, 2009)

Total Nitrogen

The total nitrogen content of the soil studied was moderate with a value of 1.6 gkg^{-1}, slightly above the critical level of 1.5 gkg^{-1} required for sustainable crop production including cassava. The moderate content of total N in the soil could be attributed to moderate organic matter of this soil, since inorganic N is accounting for only a small portion of total N in soils (Almu and Audu 2001). The moderate amount of total N reflects the amount of organic carbon in the soils. Variable response to applied nitrogen for cassava production was thus expected in this soil

Available Phosphorus

The available phosphorus value was moderate with a value of 10.50 $mgkg^{-1}$, which exceeded the critical limit of 8.0 $mgkg^{-1}$ established for crops in South Eastern Nigeria including cassava (FPDD) 1989) cited by (Onyekwere et *al.* 2020) but below the critical level of 15 $mgkg^{-1}$ extractable P recommended by Thomas and Peaslee (1973) cited by Onyekwere *et al.* (2009). This result showed that there will be response of applied P fertilizer for cassava production.

Exchangeable Potassium

The value of the exchangeable K of the soil studied was 0.18 cmol kg-^{1,} which is below the critical limit of 0.2 cmol kg^{-1} recommended for soils of South Eastern Nigeria (FPDD) 1989), for the production of cassava. This suggests that the soil will show substantial responses to applied potassium fertilizer for cassava production. As cassava roots export high amount of K from the soil (Howler, 1991)

Selected Chemical Properties

Some selected chemical properties of the soils studied are shown in Table 2.

Soil Reaction

The soil reaction expressed as pH (H_20) was moderately acidic, with a value of 5.5. the value was considered adequate for cassava production, because at this pH there will be availability of most plant nutrient for cassava uptake. Agbede (2009) observed that soil pH is master property that influences so many other physical and chemical properties of the soil such as soil nutrient solubility and availability, microbial status and activities in the soil. The moderate acidity of the soil will not pose a problem in the production of cassava because it is acid tolerant.

Organic Carbon

The organic carbon content was moderate, with a value of 2.5 gkg^{-1} . Maintenance of a satisfactory organic matter status is essential to the production of most of the Nitrogen and half of the Phosphorus taken up by unfertilized crops (Von Uxekull 1986) cited by (Onyekwere et *al.* 2020), including cassava. Therefore, increasing the level of organic carbon of the soil is necessary for cassava yield increase.`

Exchangeable Bases

The soil was low in the exchangeable Ca content, with a value of 3.32 cmol kg^{-1}.The soil had exchangeable Ca value below 4.0 cmol kg^{-1} regarded as lower limit for soils (Onyekwere *et al*, 2001). Exchangeable Mg in the soil was high with value of 3.20 cmol kg^{-1}. The soil had exchangeable Mg value that exceeded the critical level in soils (0.02 - 0.4.0 cmol kg^{-1}) established by Adeoye and Agboola (1985) cited by (Onyekwere et *al.* (2020).The high level of exchangeable Mg could be attributed to the nature of the parent material, as the total Mg content of the soil appeared to be influence by parent material and weathering (Osonwota, *et al*., 2009). Exchangeable Na content of the soil was low with a value of 0.08 cmol kg^{-1}, which is below 0.20 cmol $kg^{-1,}$ regarded as the critical value of exchangeable K needed in soils (Onyekwere *et al*., 2020)

Effective Cation Exchange Capacity

The Effective Cation Exchange Capacity (ECEC) of the soil was low with a value of 7.48 cmol kg^{-1}, as the value was below 20 cmol kg^{-1}, regarded as being suitable for crop production if other factors are favorable (Onyekwere, 2004), quoting FAO (1976). The low ECEC and nutrient reserves of the soil is attributed to the fact that soils of southeast tern Nigeria are strongly weathered, have little or no content of weatherable minerals in sand and silt fraction and have predominantly kaolinite in their clay fraction (FPDD, 1989) cited by (Onyekwere *et al.* (2020).

Performance and Yield of Cassava

Table 5 shows effect of treatments on plant height, number of leaves, girth size and fresh root yield of cassava. The results showed that the highest plant height of 2.10 m and 2.30 m was obtained with treatment 2 (0kg neem + 750 kg NPK 12:12:17+2 Mg/ha) in 2017/2018 and 2018/2019 respectively and both values were not significantly (P<0.05) different from values obtained from control and other treatments apart from treatment 3 .Treatment 5 (2,2500 kg neem + 187.5 kg NPK 12:12:17+2 Mg /ha) gave the highest girth size (7.4) in 2017/2018 but was significantly (P<0.05) different from values obtained from control and other treatments, apart from treatment 2 (750kg neem +562kg NPK (12:12:17+2 Mg /ha). In 2017/2018 treatment 6 (3,000 kg neem + 0 kg NPK 12:12:17+2 Mg /ha) had the highest girth size with a value of 8.6 cm, but was significantly different from value obtained from control only. Treatment 5 (2,250kg neem +187kg NPK 12:12:17+2 Mg /h), also had the highest number of leaves in both 2017/2018 and 2018/2019 having leave number of 56 and 59 respectively but in 2018/2019 it was significantly (P<0.05) different from the values obtained from control and other treatments apart from treatment 3 (750kg neem +562kg NPK 12:12:17+2 Mg /ha), while in 2018//2019 it was not significantly different from values obtained from control and other treatments . In terms of fresh root yield, treatment 5 (2,2500 kg neem + 187.5 kg NPK 12:12:17 + 2 Mg /ha) gave the highest fresh root yield of 44.71 t/ha in 2017/2018 and 42.35 t/ha in 2018/2019 but the yield values were significantly (P<0.05) different from the yield values obtained from control and other treatments apart from that of treatment 2 (0kg neem +750kg NPK 12:12:17+2 Mg /ha) in both years. The result of the fresh root yield is in agreement with the findings of Murwria and Kirchmann (1993) who observed that nutrient use efficiency of crops is increased through a combination application of organic manure and mineral fertilizer. Nweke and Nsoanya (2013) also reported that combination of organic manure and inorganic fertilizer gave better result than the sole application of either organic manure or inorganic fertilizer. The increase in fresh root yield could be due to synthetic effect of combination of organic and inorganic fertilizer that enhanced nutrient release and availability of Nitrogen and other macro and micro nutrients.

Table 2: Treatment Combinations

Treatment Number	Treatment/ha	
1.	Control (No application)	
2.	0 kg Neem + 750 kg NPK	(12:12 17 + 2Mg)
3.	750 kg Neem + 562.5 kg NPK	,,
4.	1,500 kg Neem + 375 kg NPK	,,
5.	2,250 kg Neem + 187.5 kg NPK	,,
6.	3,600 kg Neem + 0 kg NPK	,,

Table 3: Mean values of the physical and chemical properties of soils of the experimental sites for the two cropping seasons (2017/2018 and 2018/2019) studied

Parameter	Value
Sand (g kg^{-1})	684.0
Silt (g kg^{-1})	108.0
Clay (g kg^{-1})	208.0
Texture	Sandy Clay loam
P^H	5.5
Organic Carbon (g kg^{-1})	25.0
Total Nitrogen (g kg^{-1})	1.6
Available P (Mg /kg)	10.50
Exchangeable K (cmol / kg)	0.18
Exchangeable Ca (cmol / kg)	3.32
Exchangeable Mg (cmol / kg)	2.20
Exchangeable Na (cmol / kg)	0.08
Exchangeable Acidity (cmol /kg)	1.50
Effective Catrin Exchange capacity cmol/kg	7.48

Table 4: Chemical composition of Neem based Fertilizer

Parameter	% Composition
N	3
P	6
K	3
Organic Carbon	30

Table 5: Effect of treatment on yield and yield attributes of Cassava

Trt No	Treatment	Plant height(cm)		Girth size (cm)		Number of leaves		Fresh root yield t/ha	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
1	Control	1.90	2.02	6.0	6.7	40	49	27.67	22.61
2	0kg neem+750kg NPK 12:12:17+2/ha)	2. 10	2.30	7.1	7.7	50	53	43.76	41.12
3	750kg neem +562kg NPK(12:12:17+2/ha)	1.95	2.19	6.6	7.8	54	56	39.01	34.52
4	1,500kg neem +375kg NPK(12:12:17+2/ha)	1.95	2.13	6.5	8.7	46	57	33.63	40.42
5	2,250kg neem+187.5kg NPK(12:12:17+2/ha)	2. 00	2.21	7.4	8.1	56	59	44.71	42. 35
6	3,000kg neem + 0kg NPK(12:12:17+2/ha)	1.98	2.20	6.3	8.6	44	50	39.45	38.51
	L SD 0.05	0.25	0.39	0.30	1.09	4.02	23.32	4.13	1.79

CONCLUSION AND RECOMMENDATION

From the result of the soil studied, it can be affirmed that soil of the study area was moderately acidic, has moderate Organic carbon content, moderate Nitrogen and Phosphorous contents and low Potassium content. Therefore, incorporation of these plant nutrients into the soil for cassava production will boast yield of cassava in the study area. Result obtained from the agronomic studies revealed that neem based fertilizer alone cannot be used for cassava production. Instead the combination of 2,250kg neem + 187.5 kg NPK 12:12:17 + 2 Mg, which is equivalent to 2,250 kg neem + 150 kg NPK 15:15:15 or 2,250 kg neem + 112.5 NPK 20:10:10 or 2,250 kg neem + 83.34 kg NPk 27:13:13 is more suitable and therefore is recommended for sustainable cassava production in soils derived from Shale in southeastern Nigeria.

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COMPARATIVE EFFECT OF SELECTED FERTILIZERS ON SOIL CHEMICAL PROPERTIES OF THE PROPOSED SITE FOR CASSAVA CULTIVATION IN ONDO SOUTHWESTERN NIGERIA – INCUBATI ON STUDY

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ABSTRACT

The major aim of soil and plant analysis before planting is to detect the nutrients that are deficient before planting and possibly proffering necessary solution. Laboratory incubation study was conducted to determine the amount of OM, N, P, K, Ca, Mg as well as Fe, Cu, Zn and Mn released to the soil proposed for cassava cultivation by NPK 15:15:15, urea, single super phosphate (SSP), muriate of potash (MOP), wood ash (WA) and poultry manure (PM). Soil samples were collected from the field proposed for planting cassava in Ondo southwestern Nigeria. Three hundred grammes of soil samples were used for the experiment. Poultry manure and wood ash were each applied at 0.5 g and mineral fertilizer types were each applied at 0.2 g /300 g soil. The treatments were incubated for 30, 60 and 90 days. The pretreatment analysis showed that the soil was slightly acidic, low in N, P, Ca, K and fairly adequate in micronutrients. All the treatments decreased soil pH at 30 days. All the nutrients were increased at 30 days of incubation and thereafter decreased at 60 days and 90 days. Among the fertilizers, application of NPK 15:15:15 fertilizer had better balanced N, P and K release to the soil for a short period while poultry manure added extra Ca and Mg to the soil in addition to N, P and K in balanced proportion and the nutrients were gradually released to the soil. Poultry manure will be the proper choice of fertilizer for crops like cassava that spend more than six months before harvesting.

Key words: Cassava, fertilizer types, incubation, soil analysis

INTRODUCTION

Molindo (2008) opines that there is inadequate scientific basis for advising farmers on the appropriate quantity of organic residues or fertilizers to be recommended to farmers after incubation of organic residues in the soil that, planting should be done. Sustainable crop requires appropriate fertilizer use. Over-application of farm inputs leads to waste and low profit. Inadequate nutrients supply usually leads to soil nutrients depletion (Howeler, 2002). Adequate plant nutrition leads to good photosynthesis, good growth and increase in quantity and quality of harvests. Pre-planting planning of fertilizer application focuses on knowing the nutrients deficient in the soil and applying actual dosage of the plant requirement in order to ensure balanced nutrition (Janssen, 2011). It has been established that there is either synergistic or antagonistic interactions of nutrients in the soil. For example, there is positive interaction between N and P (Ayeni and Adeleye, 2011).
The uptake of N and P by plants usually lead to higher yield while there is nutrient

antagonism between K and Mg as well as Ca. High rate of K fertilization may lead to reduction in Mg or Ca uptake. This is because cations such as K, Ca and Mg usually compete for plant uptake. There is also synergistic relationship between S and N. Excess P concentrations may lead to reduction in Zn uptake by plants. Plants require all the fourteen essential nutrients (N, P, K, Ca, Mg S, Fe, Cu, Zn, Mn, Mo, Co, Na and Be) for optimum growth and yield in adequate quantity and in balanced proportion (Ayeni, and Adetunji, 2010). This is the essence of soil and plant analysis before planting is done. Incubation and analysis of the nutrients present in the fertilizers before direct application to the main field will show the synergistic and antagonistic effects on the plants and the soil.

Cassava is known as a common man's food and its production is also known as poor man's business because it is cheap with low cost of production. Cassava tolerates any type of soil provided it has minimum nutrients. It can be grown in any soil where other crops fail to perform. Despite the fact that cassava can grow in any type of soil but it may not be able to reach its optimum performance. Cassava needs balanced nutrients for better growth and yield. On the assumption that cassava can perform on any type of soil, literatures on the nutrients requirement of cassava are scanty compared with literatures on other crops such as maize especially in Ondo where this experiment is sited.

Manures are the substances which provide nutrients for proper growth of plants. During shifting cultivation era, cassava did not require additional nutrients from external sources. Due to continuous cultivation of the available lands, most of the nutrients required for the optimum production of cassava have been used up. Sittibusaya & Kurmarohita (1978) in an experiment conducted in south east Thailand, report that after 15 years of continuous cassava production without fertilizer application the yield of cassava tubers dropped from 30 t/ha to 17 t/ ha. Literature has revealed that cassava required considerable amount of N, P, Ca, Mg and some minor nutrients. Vanlauwe *et al.*, (2008) opined that cassava required considerable amount of N, P and K but preferable K. For example, Vanlauwe *et al.*, (2008) maintained that cassava tubers require large amount of K with the ratio of 5:1:10 of N: P: K respectively in comparison with other crops with ratio 7:7:7 N: P: K. Cassava required N for vegetative growth at the early stage of its development.

IFA (1992) affirmed that cassava requires low amount of P but when the soil is used to grow crops continuously, the soil may be depleted in P to the extent that the available P in the soil may not be sufficient for cassava utilization for optimum yield. Phosphorus may not be as essential as potassium in cassava production because P is majorly known for seed formation and ripening of fruits. The little amount of P required in cassava production is mainly for root formation and energy transfer in form of adenosine diphosphate (ADP) and triphospate (ATP).

Potassium requires K for carbohydrate formation and tuberization (IFA, 1992) which is the major component of cassava (Ezui *et al*., 2016). Potassium also helps in water uptake from the soil, regulates the balance between assimilation and respiration in plants. It also improves net assimilation of nutrients in cassava roots which results in vigorous growth and reserve assimilates called tubers. (Jansson, 1980). Howeler (1981) affirmed that there is synergistic relationship between N and K in optimum production of cassava. Nitrogen helps in vegetative growth while K helps in tuber formation; thus the absence of one leads to poor growth and yield.

Susan John *et al.* (2010) maintained that a farm grown with one hectare of cassava will produce 30 metric tonne of fresh tuber and will remove as much as 180-200 kg N, 15-22 kg P_2O_5 and 140-160 kg K_2O from the soil. Howeler, (1981) states that, on an average, cassava extracts about 4.91, 1.08, and 5.83 kg of N, P, and K, respectively, per ton of harvested tuber. Howeler, (1981) and Kanapathy (1974) state that, cassava requires 4.91, 1.08, and 5.83 kg for N, P and K respectively in tropical soils for cassava to attain the tuber yield of one ton/ha. This is the main reasons why this experiment to test the mineralization rate of nutrients by the selected organic manures and mineral fertilizers was conducted within three months of planting of cassava. Hence, the objective of this study was to evaluate the potentiality of fertilizer types in increasing soil nutrients for cassava production.

MATERIALS AND METHOD

Routine soil Analysis

Fifty core soil samples were randomly taken from the entire experimental field at 0-20 cm depth for nutrients analysis to determine the nutrients status of the soil. Parts of the soil samples were used for incubation study. The collected soil samples were bulked, air-dried and sieved through 2 mm sieve mesh. The nutrients that were analyzed were OM, Total N, available P, exchangeable K, Ca and Mg as well as Fe, Cu, Mn and Zn.

Laboratory Incubation Study

A laboratory incubation study to determine the nutrients released from wood ash, poultry manure, single super phosphate, muriate of potash, calcium ammonium nitrate (CAN) and NPK 15:15:15 fertilizers at 30, 60 and 90 days was carried out at the laboratory of the Department of Agricultural Science, Adeyemi College of Education, Ondo. The assertion of Spear *et al.* (1979) was the reason why 90 days was used for this experiment. The experiments performed by Spear *et al.* (1979) on the nutritional requirements of cassava showed that the youngest fully expanded leaf (YFEL) blades at 3-4 months after planting provided the best nutritional indicator for nutrients present in them especially K.

Experimental Procedure and Treatments Application

Three hundred (300) g of air-dried soil sample was weighed into 18 different plastic cups and labeled according to the treatments applied. Poultry manure and wood ash at 1.25 g to represent 10 t ha^{-1} and mineral fertilizer types at 0.6 g to represent 400 kg ha^{-1} were used as treatments in the experiment. Fifty (50ml) of water was added to the content of each container. The containers used for the experiment were covered with foams in order to reduce volatilization of nutrients. The samples were them incubated for three months. During the period of incubation, 50 ml of water was added at two weeks interval till the termination of the maturity period of most arable crops. At the completion of the incubation period, the incubated soil samples were air-dried for nutrients determination.

Soil Chemical Properties

Soil pH was determined using glass electrode pH water in 1:2 soil water ratio and 2:1 soil $CaCl_2$ suspension (Adeoye, and Agboola, 1985) at 30, 60 and 90 days of incubation. Total N was determined by micro Kjedahl method (Bremner, and Mulvaney, 1982). This involves distillation and titration. Available phosphorus (P) was extracted by bray-1-method (Murphy and Rilley, 1962). A Modified and available phosphorus was determined colorimetically.

Exchange bases (K, Ca and Mg) were extracted with neutral ammonium acetate (I.I.T.A, 1979.). 10g air-dried soil samples sieved through 2mm diameter sieved was weighed into conical flask and 100ml of 1 mole ammonium acetate was added. Calcium (Ca), Mg, K and Na were determined from the filtrate by atomic absorption spectrophotometer (AAS). Organic carbon was determined by walkley black wet oxidation method (Nelson and Sommers, 1982). The result of the titration was multiplied by 1.33 to give percentage organic carbon. Destructive analytical method was used.

Statistical Analysis

The data collected were subjected to descriptive analysis such as means and standard deviation.

RESULTS

The routine soil analysis showed that the soil was generally low in soil nutrients, hence; needed plant nutrients from external source. The soil was slightly acidic, low in N, Ca, K and fairly adequate in cations. In the past, Nigeria soils were not used to be deficient in soil exchangeable K and not usually considered as deficient nutrient especially for crop like cassava but due to continuous cropping it has assumed the status of one of the most limiting plant nutrients.

Poultry manure was higher in OC, N, P, Fe, Cu, Mn and Zn than wood ash while wood ash was higher than poultry manure in exchangeable K, Ca and Mg (Table 2). Wood ash had lower C/N ratio than poultry manure.

Effects of Mineral Fertilizers and Wood ash on Soil pH, OC, total N and available P at 30, 60 and 90 days

Table 3 shows that all the treatments decreased the pH of the soil at 30 days compared with control except wood ash. Application of NPK, SSP and Urea decreased the soil pH as the period of incubation increased. Muriate of potash (MOP) increased the soil pH at 60 days of incubation and decreased the pH at 90 days of incubation while wood ash increased the soil pH throughout the period of incubation. Compared with control, only wood ash and poultry manure increased the soil pH up to 90 days of incubation. Among all the treatments and period of incubation, wood ash had the highest cumulative pH with mean value of 7.62.

The soil fertilized with NPK, MOP and SSP had the highest increase in total N at 60 days after incubation while the total N content of the soil samples fertilized with poultry manure and wood ash increased as the period of incubation increased. Compared with control at 30 days of incubation, only NPK and urea significantly increased total N at 60 days, all the treatments increased the total N except urea. NPK fertilizer had the highest increase in total N followed by urea at 60 days after incubation. Urea recorded the highest increase in total N at 90 days of incubation followed by NPK fertilizer. Among all the treatments and period of incubation, urea fertilizer had the highest cumulative total N with mean value of 0.26%.

Available P increased in the soil samples fertilized with addition of poultry manure as the period of incubation increased.

Mineralization of available P in NPK, MOP and SSP fertilizers reached its peak at 60 days of incubation while there was slight difference in P mineralization with addition of wood ash and urea between 60 and 90 days of incubation. Relative to control, all the treatments significantly increased available P at 30 and 60 days of incubation. Single superphosphate recorded the highest increase in P at 30 and 60 days of incubation. Among all the treatments and period of incubation, SSP had the highest cumulative P with mean value of 42.2 mg/kg.

The C/N ratio of the soil samples fertilized with mineral fertilizes, poultry manure and wood ash showed that the C/N ratios were low. The low C/N ratio was expected to favour microbial activities in enhancing mineralization of plant nutrients.

Table 5 below shows the effect of mineral fertilizers, wood ash and poultry manure on soil exchangeable K and Ca. The K content of the soil samples fertilized with NPK fertilizer, MOP poultry manure and WA increased as the incubation period increased. The K content in the soil fertilized with SSP and urea had the highest K mineralization at 2 months after incubation. Among the treatments MOP recorded the highest K followed by wood ash at 30 and 90 days of incubation while the NPK fertilizer recorded the highest K mineralization at 60 days after incubation (Table 5).

The Ca content in the soil samples fertilized with MOP, poultry manure and wood ash increased as the period of incubation increased. There was reduction in Ca content of the soil fertilized with NPK, SSP and urea 60 days after incubation. Wood ash recorded the highest Ca.

Table 1: Pre – cropping properties of the experimental site

Soil properties	value
pH (1:1H_2O suspension)	5.71
pH (2: 1.0.1M $CaCl_2$ suspension)	5.50
Organic carbon (g kg^{-1})	7.8
Organic matter (g kg^{-1})	10.1
Total Nitrogen (g kg^{-1})	0.52
C/N ratio	15
Available P (mg kg^{-1})	7.56
Exchangeable bases (C mol kg^{-1})	
Ca^{2+} ;	2.12
Na^{+} ;	0.28
K^{+} ;	0.20
Mg^{2+} ;	0.27
Exchangeable acidity (C mol kg^{-1})	1.39
Fe^{2+} ;	2.36
Cu^{2+} ;	0.67
Mn^{2+} ;	5.54
Zn^{2+}	4.91
Sand (mg/kg)	820
Silt ‘’	110
Clay ‘’	70
Textural Class	loamy sand
Local classification	Egbeda fasc, Ondo series
USDA soil classification	Alfisols (oxic tropuldalf)

Table 2: Nutrient concentration (%) of poultry manure and wood ash

Parameters	Poultry manure	wood Ash
Organic carbon	20.79	14.57
Nitrogen	1.69	0.73
C/N ratio	12	20
Total P	3.42	1.00
K "	1.40	14.00
Ca "	3.80	5.43
Mg "	0.60	3.00
Zn "	0.62	0.16
Cu "	0.22	0.36
Fe "	3.26	2.25
Mn "	3.43	2.34

Table 3: Effect of selected Mineral Fertilizers, Poultry Manure and Wood Ash on soil pH, OC, total N and available P

Treatment	Control	NPK	MOP	PM	SSP	WA	UREA
				pH			
Days							
30	5.85	5.75	5.43	5.29	5.26	7.99	5.01
60	5.81	5.5	5.68	5.08	5.19	7.39	4.48
90	5.86	5.21	5.21	5.96	5.18	7.47	4.71
MEAN+SE	5.84±0.15	5.48±0.16	5.44±0.14	5.44±0.27	5.21±0.26	7.62±0.19	4.73±0.15
SD	2.34	0.27	0.24	0.46	0.04	0.33	0.27
			OC				
30	2.3	2.71	2.34	2.32	2.35	2.25	2.26
60	2.31	2.75	2.32	2.76	2.38	2.45	2.76
90	2.31	2.71	2.35	3.23	2.3	2.61	2.76
MEAN+SE	1.31±.003	1.72±.01	1.34±.008	1.77±.26	1.34±.02	1.44±.10	1.59±.67
SD	0.005	0.02	0.02	0.05	0.04	0.18	0.29
			TOTAL N				
30	0.15	0.2	0.13	0.16	0.12	0.11	0.25
60	0.17	0.26	0.18	0.19	0.22	0.2	0.25
90	0.17	0.23	0.2	0.17	0.13	0.16	0.27
MEAN+SE	.16±.01	.23±.02	.17±.02	.17±.03	.16±.03	.16±.03	.26±.01
SD	0.01	0.03	0.04	0.02	0.06	0.05	0.01
			AVAILABLE P				
30	10.2	40.4	20.2	30.6	45.2	20.1	17.82
60	10.3	47.3	37	34.1	49.6	23.2	17.8
90	6.2	35	32.9	38.2	32.3	23.7	19.3
MEAN+SE	8.9 +1.4	40.8+3.5	27.87±.08	34.32+2.2	42.4+5.2	22.33+1.1	18.3+0.5
SD	2.24	6.17	8.76	3.8	8.99	1.95	0.86

NB: MOP = muriate of potash, NPK = NPK15:15:15,PM = poultry manure, SSP = single superphosphate, WA= wood ash

Table 4: Effect of mineral fertilizers, poultry manure and wood ash on soil C/N

Treatment	Control	NPK	MOP	PM	SSP	WA	UREA
				C/N			
Days							
30	13	14	18	14	20	20	9
60	14	11	13	15	11	12	11
90	14	11	11	19	19	16	10

Table 5: Effect of Mineral Fertilizers, Wood Ash and Poultry Manure on Soil Exchangeable Calcium and Potassium

			Ca				
DAYS	CONTROL	NPK	MOP	PM	SSP	WA	UREA
			C mol/kg				
30	2.81	5.21	5.35	5.87	3.49	6.36	4.78
60	2.91	3.39	5.03	5.95	3.91	6.65	3.59
90	2.45	4.96	5.79	6.69	4.6	9.71	6.33
MEAN + SE	2.7+.31	4.5 +.9	5.4+.22	6.2+.26	4+.32	7.6+1.1	4.9+.79
			K				
DAYS	CONTROL	NPK	MOP	PM	SSP	WA	UREA
30	0.33	0.73	0.75	0.47	0.42	0.7	0.37
60	0.32	0.82	0.77	0.49	0.41	0.79	0.32
90	0.31	0.98	1.78	0.54	0.32	1.34	0.36
MEAN + SE	.32+.001	.84+.07	1.1+.34	.5+.01	.38+.03	.94+.2	.35+.02

DISCUSSION

Wood ash consistently increased the soil pH throughout the incubation period compared with all other treatments. This might be as a result of high potassium and calcium content in the wood ash. This corroborates with the earlier research conducted by Moyin – Jesu (2007) and Ojeniyi et al., (2007) who concluded that wood ash, cocoa pod husk and rice brain applied at 8 t ha^{-1} increased the soil pH. The ability of poultry manure (PM) to increase the soil pH at 90 days might be as a result of high Ca and Mg content of the poultry manure used in the conduct of the experiment. Nguyen (2010) reports that poultry manure improves soil fertility and reduces soil acidity and toxicity (Al) in soil profile. Olatunji *et al* (2012) recommended poultry manure as a valuable source of plant nutrient and soil amendment whose adoption needed to be encouraged in pasture management as well as other minerals needed for plant use. Olatunji *et al* (2012) advocated for the use of poultry manure to improve the soil pH and other cations.

On OC mineralization, no major difference was observed at 30 and 60 days of incubation. Researches on OC have shown that mineral fertilizers increase OC (Wei *et al.,* 2011) but; it was observed that there were net losses in OC in the soil samples treated with NPK 15:15:15, MOP and urea fertilizers at 90 days of incubation showing that mineral fertilizers were of little or no benefit for OC. This might be as a result of loss of OC in form of carbon iv oxide. This observation might be different on the field where plants and animal residues are in contact or mixed with mineral fertilizers. This work is in line with the assertion of Guo et al., (2019) who observed that mineral fertilizers did not affect soil OC in the experiment conducted on the effects of long – term fertilization on soil OC mineralization and microbial community structure. Among all the treatments and period of incubation, poultry manure had the highest cumulative OC with mean value of 1.77%.

The low release of potassium (K) in urea and SSP fertilizers might be as a result of lack of K in SSP formulations. At 60 days of incubation, all the treatments increased K content except urea fertilizer. This research is in line with the earlier research conducted by Ujwala Ranade (2011) who observed that wood ash can increase potassium along with other nutrients.

This research also corroborates the earlier research conducted by Ayeni and Adetunji (2010) that organic wastes increased soil N, P, Mg, K and Ca.. Delaune et al (2004) observed increased in N, P, Ca and K when poultry manure was applied to the soil.

On cassava production, going by Kang (1981), Howeler, (1998), Howeler and Spain (1978) and Vanlauwe *et al.*, (2008) using mean values of the nutrients obtained in the research, the soil pH range was favourabe for optimum production of cassava. The following nutrient values were recommended, OM, 3.1% (high), available P (mg/kg) <2.2 -4 very low, 4-15 low and > 15 high, K (C mol/kg) < 0.10 very low, 0.10 – 0.15 low, 0.15 – 0.25 medium and > 0.25 high. The critical levels of exchangeable Ca (C mol/kg) for cassava production are, < 0.25 very low, 0.25 – 1.0 low, 1 – 5.0 medium and > 5 high (Hagens and Sittibusaya. 1990, Howeler, 1978; and Howeler, 1998).

Relative to control, all the treatments significantly decreased ($P<0.05$) the total nitrogen at 90 days except muriate of potash. The inability of the total N to be increased by SSP and MOP at 30, 60 and 90 days of incubation might be as result of low N content in their formulations. Nitrogen is known to be abundant within pH range of 5.6 – 9, P between 6 – 8 and K 6 - 9. Averagely, the productive soil is expected to have pH value of 5.5 – 7.5 (Sobulo and Osiname 1981, Adeniyan *et al.*, 2006, Ojeniyi, 1995; Ayeni, 2020) averagely, the productive soil is expected to have pH range 5.5 – 8.5. Hence, the pH recorded in this research is conducive for the release of nutrients that will give optimum yield of cassava. Cassava can perform well from slightly acid to neutral soil (Howeler and Cadavid (1983). The ability of NPK and urea to release total N might be as a result of high amount of N present in NPK and urea compositions that was easily released to the soil within one month of incubation. Han *et al.* (2016) observed that NPK has high nutrient contents and are rapidly taken up by plant. However, alongside with NPK and urea, wood ash and poultry manure increased the total N at 60 days of incubation. This result is in line with the work of Ayeni *et al*., (2015) who observed that burnt agro-wastes increase total N at 90 days of incubation. Despite the fact that the **a**mount of NPK and urea applied to the soil were lower than the rate of wood ash and poultry manure applied to the soil yet NPK and urea performed better than the organic wastes. Chen (2006) affirmed that organic wastes have a number of shortcomings, including low nutrient content, slow decomposition and different nutrient compositions depending on its organic materials.

The available P released to the soil was high in NPK, MOP, SSP and wood ash while P was low in urea and very low control experiment.

Calcium was in the medium range for NPK, MOP, SSP and urea and very high for poultry manure and wood ash. The very high Ca in poultry manure and wood ash might result in nutrients antagonism. The soil was originally high in K. Potassium might not be a problem for optimum performance of cassava.

CONCLUSION

The experiment was targeted at comparing selected mineral fertilizers, wood ash and poultry manure on nutrients release for optimum production of cassava in a nutrients depleted soil. The selected fertilizers vary in nutrients composition and each fertilizer tends to add the corresponding nutrients to the soil. Among the mineral fertilizers, application of NPK 15:15:15 fertilizers had balanced N, P and K release to the soil for a short period while poultry manure added extra Ca and Mg to the soil in addition to N, P and K in balanced proportion and the nutrients were gradually released to the soil. Poultry manure will be the proper choice for enriching the soil with the nutrients for crops like cassava that will spend more than six months in the soil.

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EFFECT OF SEED SOURCES ON PHYSIOLOGICAL ATTRIBUTES OF FARMER SAVED PEARL MILLET (*Pennisetumglaucum L)* IN THREE AGRO-ECOLOGICAL ZONES OF NIGERIA

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ABSTRACT

Source of seed, parent materials, genetic composition and environment factors are germane to seed quality. A study was conducted in three agro-ecological zones of Nigeria to investigate sources, status, quality and storage conditions of Pearl millet (*Pennisetumglaucum* L.) seeds. The seed samples were collected from Jimeta (Adamawa), Gidan Kaya (Sokoto) and Gagarawa (Jigawa)in Northern guinea savanna, sahel savanna and sudan savanna ecological zones,respectively. In the ecological surveyed, 83.3 % of farmers were using farmer saved seeds while 16.7 % were using improved pearl millet seeds. Laboratory purity analysis test results indicated that Gagarawa had pure seeds of 99.01%, Gidan Kaya 96.51% and Jimeta 94.39% with corresponding Inert matters as 0.99%, 1.79% and 5.32%, respectively. The non-millet seeds observed were Gagarawa 0.00%, Gidan Kaya 1.81% and Jimeta 0.21%. The results were significantly different at P<0.001 from one ecological zone to another. The germinability test of Millet seed varied highly significant (P<0.001) from one ecological zone to another with Jimetarercording 77.91% , Gidan Kaya 82% and Gagarawa 92%. The study recommended that farmers that uses farmer saved pearl millet, Gagarawa seed sourced is proposed to be better among the examined sources for healthier seeds due to highest germination percentage and vigour index recorded.

Keywords: seed quality, agro-ecology, germination, seed purity

INTRODUCTION

Millet is a cereal crop plant belonging to the grass family, Graminae. The term "millet" is used loosely to refer to several types of small seeded annual grasses (Shobana*et al.,* 2013), belonging to species under the five genera in the tribe Paniceae, namely Panicum, Setaria, Echinochloa, genera are widely distributed throughout the tropics and subtropics of the world (Abdusalaam and Shenga, 2011). According to Sugri*et al*., (2011) the most important millets are pearl millet (*Pennisetumglaucum*) finger millet (*Eleusinecoracona*), proso millet (*Panicummiliaceum*) and foxtail millet (*Staliaitalica*). But according to Rathore *et al*., (2016), the most important cultivated millet species are: pearl Millet (*Pennisetumtyphoides*), also known as bulrush millet; proso millet (*Panicummiliaceum*), also known as common millet; foxtail millet (*Setariaitalica*); Japanese barnyard millet (*Echinochloacrusgalli* var. *Frumentacea*or *E.*

colona (Sawa)); finger millet (*Eleusinecoracona*) also known as birds food millet (Mathanghi and Sudha, 2012). Millets represent a collective term referring to a number of small-seeded annual grasses that are cultivated as grain crops, primarily on marginal lands in dry areas of temperate, subtropical and tropical regions. They are regarded as a subsistence product and generally looked upon as a famine crop for the poor. The statistical documentation for millet is generally poorer and more fragmented than that for rice and wheat despite its nutritional superiority (Radhouane, 2012).

Pearl millet (*Pennisetum glaucum* L. R. Br.), known as gero/maiwa/dauro in Hausa language, is a robust, quick growing cereal grass with large stems and leaves which are tall and vigorous, with exceptional grain and fodder yielding potential (Ankush *et al*., 2016). It is one of the most important dual-purpose crops and a staple for millions of people in Nigeria. Pearl millet, commonly called millet, is an important cereal crop mainly grown in the Northern part of Nigeria (Kaur *et al*., 2014). The crop thrives well in locations where rainfall does not last long enough to deter its growth. Over 60% and 30% of croplands are devoted to millet in Borno and Adamawa States, respectively (Verma and verma, 2014). Pearl millet is a staple food in millions of homes in Nigeria, especially among the poor, mainly in Northern Nigeria. It is also used in making a popular fried cake known as "masa". Its flour is used in preparing "tuwo", a thick binding paste (Javorski*et a*l., 2018). It contains 18% protein, is rich in vitamin B especially niacin, B6 and folic acid. It is ideal for making flat bread because it lacks gluten (Radhouane *et al*., 2013). It is an important food across the Sahel States of Borno, Yobe, Jigawa, Katsina, and Sokoto in Nigeria. It is often ground into flour, rolled into large balls, parboiled, liquefied into a watery paste using fermented milk and then consumed as "fura" or "tukura", a popular beverage in northern Nigeria (Ankush *et al*., 2016). Millet is an excellent forage crop because of its low hydrocyanic content. The green fodder is rich in protein, calcium, phosphorus, and other minerals with oxalic acids within safe limits (Yadav *et al*., 2012. Pearl millet has significant potential as feed and food grain in addition to its current use as forage (Rai*et al*., 2008). Nutritional Importance of Pearl millet Pearl millet is about the most nutritious of the cereal family. On the average, it has higher crude protein content than sorghum, maize, rice and wheat. It contains high amount of dietary fibre (Mathanghi and Sudha .,(2012). Vitamin B-complex, essential amino and fatty acids and vitamin E. It is high in minerals including iron, magnesium, phosphorous, potassium, zinc, calcium and copper. It also contains foliate and possess phytochemicals that lower cholesterol Kumar *et al*. (2016).

However, as rich as this crop is, sources of seeds are very important in crop production, as this germane to its quality and quantity. Seeds of inferior quality result into poor germination and vigour, or may contain seed-borne pathogens which may be transmitted to the developing crops (Abdusalaam and Shenge, 2011). Farmers incur financial and yield losses as a result of buying seeds of inferior quality (Yadav *et al.*, 2012). Fundamentally, seeds are means of reproduction, and most seeds are the product of sexual reproduction which produces a remixing of genetic material and phenotype variability on which natural selection acts. It is considered as one of the important basic agricultural inputs for obtaining higher yield (Chaturvedi *et al*., 2008). Good quality seed acts as a guarantee for realizing the potential of all other inputs in agriculture. It is generally assumed that populations within the same regions of provenance are derived from the same random mating or base population (Adebisi *et al*., 2019). The genetic component of this variation among populations from different regions, cantherefore, be identified by testing different seed sources and exploited through selection of superior populations for seed collection. Quality seed has been recognized as an important input in crop production and is considered essential for increasing seed production (Daniel *et al*., 2012). Obute *et al* (2019) reported the effect of poor quality seed source in germinationand yield of Soya bean. Without good seed, the investment on fertilizer, water, pesticides and other agricultural inputs will not yield the desired dividends. One of the key factor to be considered before going into millet production is knowing the source of seeds as this help to determine the quantity, quality of seed, yield potential and pest resistance potential (Jalgaonkar *et al*., 2016). Sequel to the above, the objective of the study was to investigate theeffect of seed sources on physiological attributes of farmer saved Pearl millet (*Pennisetum glaucum L.)* in three agro-ecological zones in northern Nigerian (North guinea savanna, Sahel savanna and Sudan savanna, respectively).

MATERIAL AND METHODS

Study Area

Field survey was conducted from August to September 2020 to sample the various opinions of farmers with the collaboration of the Agro allied and farmers" association in various ecological zones of Adamawa, Sokoto and Jigawa states. In the ecological surveyed, 83.3% of farmers were using farmer saved seeds while 16.7 % were using improved pearl millet seeds from research institutes. The criterions used in selection of agro-ecological zones were based on differences in climatic factors of different altitudes, longitude and Latitudes (Table 1). These factors have influence on occurrence and severity of pest infestation due to various moisture content % and post-harvest handling technics.

Laboratory Seed Quality Test

Source of Seed Material

Five kilogram each of Pearl millet Seed samples were purchased from farmers saved seeds in Jimeta (Adamawa), Gidan Kaya (Sokoto) and Gagarawa(Jigawa) ecological zones. These comprises of seed producers and seed merchants from each ecological zones. The samples were stored in a moisture proved polythenbags and stored before usage.

Seed Purity Analysis

The seed samples were taken to seed laboratory of National Cereals Research Institute Ibadan, Nigeria for seed quality tests which were purity analysis, moisture content and viabilitytest. Composite samples were thoroughly mixed using a Boerner divider and after a thorough mixing, 90 g from each seed samples were taken for purity analysis according to ISTA Rules (ISTA, 2008b). The seed samples taken were then poured on a purity analysis table. Seed samples were analysed into pure seeds (seeds of *P. glaucum*), inert matter (chaffy materials, sand, soil particles, plant parts, live and dead insects and animal droppings and particles of any seed which is less than half in size and other seeds (any crop or weed seeds other than *P. glaucum* and weed seeds). These components were then weighed separately using a precision balance. The percentage by weight of each component fraction was calculated using the following formula:

$$\text{Component (\%)} = \frac{\text{Weight of each component fraction}}{\text{Total test sample weight}} \times 100$$

When percentages of allthe three components were added together, they were equal to 100. Fractions of components less than 0.05 % were recorded as "trace". The pure seed fraction was used for seed germination test

Seed Germination Test

The pure millet seed portions obtained after purity analysis were used for germination test. Four hundred (400) seeds were taken from each sample using halving-method (ISTA, 2008a). Three replicates of 100-seeds of each genotype were germinated in 9 cm diameter petri dishes ISTA papers were used as substrate in the millet seeds germination test and placed inside an incubator at 25^{o}C. The average of 100 seeds per replicate (4 replications) were expressed as a percentage by number of the following categories.

Normal seedlings- Those which show potential for continued development into satisfactory plants when necessary conditions are provided.

Abnormal seedlings -Those which did not show the potential to develop into normal plant when grown in good quality soil and under favourable conditions of moisture, temperature and light.

Hard seeds- Those seeds which remained hard at the end of the test period because they could not imbibe water.

Fresh seeds -Those seeds which fail to germinate under the condition of germination test but remain clear and firm and had the potential to develop into the normal seedlings.

Dead seeds -Those seeds at the end of the test period were neither hard nor fresh nor have produced any part of a seedling.

However, the percentages of normal, abnormal and dead seeds were calculated by using the formula:

$$\text{Component (\%)} = \frac{\text{number of each component counted}}{100}$$

The percentages were calculated to the nearest whole number after calculation of tolerance for germination test (ISTA, 2008a; 2008b).

Moisture content:

A 2 g (initial weight) of each pearl millet samples was weighed out into a crucible and placed in the oven at 103°C for 17 hours after which the samples were brought out and allowed to cool down (for 5 minutes) in a dessicator. The samples were then reweighed (final weight) to determine the percent MC of the seeds. The MC was then computed thus;

$$\text{M.C. (\%)} = \frac{\text{Initial weight of the seed} - \text{final weight of seed samples}}{\text{Initial weight of seed samples}} \times 100$$

Data Analysis

This experiment was laid out in RCBD with three replications; each ecological samplewas regarded as block. Data from survey were analysed by SPSS 16 edition for windows computer software. Chi-square was used to test for the variable relationships and to determine mean differences. Significance levels of 0.05 and 0.001 were selected as the criterion for determining a significant difference. Data obtained from purity test and seed germination tests was analyzed.

RESULTS

The effect of seed source on pearl millet seeds moisture content, purity analysis and germination potential was presented in Table 2. Seeds sourced from Gagarawa (Jigawa) had the lowest moisture content with (11.10) while highest moisture content was recorded in seed sourced from Jimeta (Adamawa) (11.81). Similarly, Seed sourced from Gagarawa (Jigawa) had the highest pure seed (99.01%) and normal seeds (87%) with lowest inert matters (0.99%), dead seeds (10.75) and other seeds. This was closely followed by seeds sourced from Gidan Kaya (Sokoto) with moisture content of (11.14), pure seeds of 96.51% while the lowest pure seeds (94.39%) and normal seeds (74.40%) was recorded in seed sourced from Jimeta(Adamawa).

Table 1: Characteristics of agro-ecological zones and source of pearl millet seeds used in the study

Zone	Altitude (m) above sea level	Average annual rainfall(mm)	Average annual Temp.(^oC)	Longitude	Latitude
Jimeta(Northguinea savanna)	157.64	115.39	35.96	12.39	9.32
Gidan kaya(sahel savanna)	304.3	34.38	31.67	5.247	13.005
Gagarawa(sudan savanna)	372.98	42.97	31.23	9.561	12.221

Table 2: Effect of seed source on pearl millet seed moisture content, purity and germination potentials

Seed source	MC(%)	SEED PURITY TEST					
		PS	IM	OS	NS	AS	DS
Jimeta (Adamawa)	11.81b	94.39b	5.32b	0.21a	74.40b	4.90a	20.70a
Gidan kaya(Sokoto)	11.14ab	96.51ab	1.79a	1.81a	85.90ab	3.55a	8.55a
Gagarawa(Jigawa)	11.10a	99.01a	0.99a	0.00a	87.00a	3.25a	10.75a
F test 0.05	***	***	***	NS	***	NS	NS
LSD0.05	0.65	3.01	2.80	2.69	6.00	0.26	5.58
S.E	0.32	4.73	0.97	0.98	2.14	0.76	2.01
C.V (%)	9.21	4.80	78.10	65.10	20.20	50.10	113.10

PS= pure seeds, IM= inert matter, OS= other seeds, MC= Moisture content. 2 NS= normal seedlings, AS= abnormal seedlings, DS= dead seedlings. Means followed by the same letter (s) within the column are not significantly different at 5% probability level, (LSD) test.CV =coefficients of variation, NS= not significant, * = significant at $p \leq 0.05$, ** =highly significant at $p < 0.01$, *** = highly significant at $p < 0.001$

Table 3: Effect of seed source on pearl millet seed physiological attributes

Seed source	SGR(%)	SGP(%)	MGT	CVG
Jimeta (Adamawa)	13.05 ^{b}	77.91^{ab}	5.17 ^{a}	97.36 ^{b}
Gidan kaya(Sokoto)	14.76^{ab}	82.41^{ab}	4.96 ^{a}	1O3.76 ^{a}
Gagarawa(Jigawa)	17.56a	92.06 ^{a}	4.85 ^{a}	105.62 ^{a}
F test 0.05	**	***	NS	NS
LSD 0.05	0.61	3.12	2.65	2.40
S.E	0.35	4.79	0.81	0.92
C.V (%)	9.21	4.80	78.10	65.10

Means followed by the same alphabets along the columns within a character are not significantly different from one another at 5 %

probability using LSD.SGR-Seed germination rate,, SGP-Seed germination percentage, MGT-Mean germination time, CVG- Co-efficient of velocity of germination.

Effect of seed source on pearl millet seed physiological attributes was presented in Table 3.Seed sourced from Gagarawa(Jigawa) had the highest seed germination rate (17.56%) which was closely followed by seed sourced from Gidan Kaya (14.76%) while seed sourced from Jimeta had the least, Similar result was recorded for seed germination percentage with highest recorded from seed sourced from Gagarawa (92.06%), closely followed by seed sourced from Gidan Kaya (82.41%) while the least was recorded in seed sourced from Jimeta (77.91%).No significant difference was observed in mean germination time and co- efficient of velocity of germination across all the agro-ecological zones.

DISCUSSIONS

The results from this study indicated that seeds sourced fromsudan savanna agro-ecological (Gagarawa) had an overall best performance both physiologically and purity wise. This can be attributed to the climatic condition of the area which perhaps favors the storability of the pearl millet in the Gagarawa. The crop flourishes in area with less rainfall, high altitude with relatively moderate temperature. Gagarawa was found to have an average rainfall of 42.97 mm which translated to raining only for just four months (4) with more than seven (7) months of dryness with no rain, couple with an altitude of 372.98 mm, might just give the pearl millet seeds better storability performance over others in storage. Adebisi *et al*., (2019), suggested that these could also be attributed to genetically modified characters such as moisture content of the seeds and relative humidity which were lower in Guinean savanna environment, prestoragehistory of the seed and biotic agent. Kancha *et al.* (2017) and Elli *et al*. (2019) reported that one of the major factors influencing seed longevity is seed moisture content of the storage environment. Within limits, the higher the seed moisture content, the faster the decrease in germination capacity and ultimately a reduction in the overall quality of the seed.Most farmers stored seeds in the house where household activities were also taking place. Amongst the factors that influences conservation of viability and vigor of seeds, were initial physiologic quality of the seed, vigor of mother plant, climatic conditions during maturity, mechanic damages during and after harvest, action of microorganisms and insects, drying conditions, proper water content, relative humidity, storage temperature, types of packaging and storage length (Cristiana *et al.* 2017). According to Javorski *et al* (2018) control of storage environment is essential in order to increase viability period of seeds through metabolism reduction; hence conservation of the nutritional reserves. Mihafu *et al* (2017) outlined several desirable categories of packaging materials which are: porous or permeable (do not prevent the air exchange between the seeds and the environment as screens of cotton and cardboard), semi-permeable (resistant to circulation of water vapour and of exterior air as bags of multilayered Kraft paper type and polyethylene) and hermetic or impermeable (do not allow for water vapour exchanges as metal and glass containers). However, Daniel *et al.* 2012 in maize seeds, Verma and verma, 2014 and Obutev*et al.* 2019 in soybean used several containers for storage but in all glass bottle had the better seed longevity, followed by plastic can while seeds stored in gunny bags lost its viability 300 days after storage. Rathore *et al*.,(2011) proposed air tight aluminium can containers as the best storage option for farmers living in rural areas under ambient condition (28 - 32^{o}C) with no modern day storage facilities. According to Abdusalaam and Shenge (2011) these moisture contents are mostly favourable for growth and development of seed-borne fungi and other microbes. This relationship was also mentioned by Jalgaonkar *et al.* (2016) that high temperature and concomitant result in high relative humidity in the store which finally reduce seed viability due to increased degree of invasion by seed-borne or storage fungi. The purity analysis of samples from Jimeta (Adamawa) and Gidankaya (Sokoto) also show that most samples had high contents of inert matters which may increase the moisture contents and temperature of stored seeds. According to Javorski *et al.,* 2018, the increase in respiration rate of seed either due to inert matter or any other cause may lead into release in its composition water to environment hence the increase in relative humidity within packaging material. When this happens seeds will adjust themselves to the new relative humidity and then acquire more elevated moisture content than initial amount. Seed germination test is normally conducted in the laboratory in order to determine the percentage of live seeds in a sample (Ankush *et al*., 2016). The viable seed is capable of producing normal seedlings under favourable germination conditions. This test is necessary for seeds which are produced for commercial use within a country or abroad (Sugri *et al*., 2011).

CONCLUTION AND RECOMMENDATION

From this study, the sourcedpearl millet seed from Sudan savanna agro-ecological zone (Gagarawa) had the least inert materials, maximize high germination percentages and low disease incidence. The seed from the agro-ecological zone was outstanding in all the seed quality attributes evaluated and should be the preferred farmers' saved seeds for farmers in the agro-ecological area, thus recommended. However, more emphasis should be made on the production and distribution of pearl millet seeds produced from Research institutes and Agricultural development agencies to provide small scale farmers with improved seeds at affordable prices.

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MYCOTOXINS CONTAMINATION OF SORGHUM GRAINS FROM DIFFERENT ECO-NICHES IN NORTHERN GUINEA SAVANNAH AGRO-ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT

Surveys were conducted on the extent of mycotoxins contamination of Sorghum samples from three eco-niches in the northern guinea savannah (NGS) agro-ecological zones. The NGS was delineated into five major sampling locations (Babanna, Kontagora, B/ Gwari, Sabuwa and Maiduguri) termed "Districts" and each district was further sub-grouped into five locations from which the samples were collected from the three eco-niches. A multi-mycotoxin extraction method with modifications was employed for extractions of all the AFs, ZEA, OTA and DON. The extraction of FBs and clean-up was done according to the method of Sydenham *et al*,. Afatoxins and other four mycotoxins were individually determined using HPLC with fluorescence detection. Specificity, accuracy, linearity and detection limits were the determinants validated to ensure the reliability of the method employed. Samples from the stores, market and field had values of 471.30± 82.13, 228.60± 34.80, 137.20± 26.73 µg/kg) for aflatoxin(s) in descending order. Concentrations of 1890.00± 34.20, 1636.80± 17.00 and 1083.40± 21.00 µg/kg for fumonisins in samples from field, store and market respectively was obtained. In the case of ochratoxin contamination, field, market and stores had respective values of 92.93± 3.20, 88.75± 3.20 and 66.90± 4.3 µg/kg in descending order. Mean level of 1192.00± 11.40 , 1125.50± 26.00, 360.40± 12.40 µg/kg were recorded for Zearalenone in the field, market and store respectively. Deoxynivalenol had values of 1227.00± 25.00 M, 1134.50± 23.45 F and 583.00± 10.70 S µg/kg recorded from the market, field and store respectively. It suffices to state that, mycotoxins contamination of sorghum grain in all the eco-niches in this agro-ecological region is far above recommended level

Key words: Northern guinea savannah, Eco-niches, Mycotoxins, Contamination, HPLC/MS

INTRODUCTION

Food security connotes access by all people at all times to safe and nutritious food needed to maintain a healthy and active life (FAO, 2005). In Nigeria, the estimated post- harvest losses in grains such as sorghum and millet is enormous; storage is responsible for the maximum loss (7.5%). For regular availability of agricultural outputs or stabilizing the economy of any country, it is required that quality food grains must be supplied to the consumers for making different products and marketing, as well as to the farmers for sowing and growing healthy grains (Wright and Cafiero, 2011).

Out of the eight billion people on the planet, a striking one billion are living in extreme poverty, which represents one-seventh of the world's population. Extreme poverty does more than deprive people of necessary food; it also robs them of safe drinking water, sanitation, education, shelter, etc. In fact, more than a billion people live on less than $1.25 a day, which isn't even enough to buy one gallon of milk at market price. At a global level, the number of people suffering from hunger and poverty exceeds one billion, (Embrace relief, FAO, 2009, 2021).

Lack of adequate storage and processing facilities has been the major cause of damage to substantial amount of food grains after harvest (Adesina *et al*., 2019). Postharvest loss can be defined as the degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product.

Food and Agricultural organisation (FAO) has estimated the worldwide annual losses in stored produce to be as much as 10% of all stored grain (Parfitt *et al*., 2010). Food grain losses that ranges between 25– 40% is incurred in Sub-Saharan Africa, which mostly occur during storage at the farm level (Adesina *et al*., 2019). Rajashekar *et al*., (2012) stated that, Post-harvest losses in India and some Sub-Saharan Africa countries were found to be in the range of 12 to 16 million metric tons of food grains per year; this amount of grains, the World Bank stipulates could feed one-third of poor Indians and two-third of poor Nigerians.

The grain value chain in Nigeria has tremendous opportunities and growth potential. An estimated 25 million metric tonnes (MT) of grains are produced annually and the grain market is expected to grow by 2.5% – 3% per annum (FMA, 2013). The annual production of maize is estimated at 10.7 million MT, 7.6 million MT of rice, and 6.8 million MT of sorghum (NGI, 2020). This places Nigeria as the largest producer of maize in Africa, the second-largest producer of rice and beans in Africa, and the second-largest producer of sorghum in the world (Baributsa, and Njoroge, 2020). However, despite these opportunities, the FAO estimates that as much as 3 million metric tonnes across all grains are lost after harvest. Further reports indicate that more than 30% of staple food grains (maize, sorghum, millet) are lost specifically due to poor storage (ReliefWeb, 2021). Between the 2018/19 market year, production levels for maize fell by almost 3% as a result of pest infestations during the production and storage phases (NGI, 2020). Another 13% decline is estimated in the 2020/21 market year due to poor storage capacity and COVID-19 restrictions disrupting market access. For fruits and vegetables, post-harvest losses reach up to 45% of the 23 million tonnes produced annually. (Fatima, 2021).

Mycotoxins are toxic compounds that are naturally produced by certain types of moulds (fungi). Moulds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Mould growth can occur either before or after harvest, during storage, on/in the food itself often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing (FAO/WHO, 2018). Conditions that promote fungal growth may not always lead to mycotoxin production. However, generally, a temperature range between 25°C, and 30°C, a water activity (aw) higher than 0.78, and relative humidity between 88% and 95% are considered as favorable for fungal growth and subsequent mycotoxin production.

Several hundreds of different mycotoxins have been identified, but the most commonly observed mycotoxins that present a concern to human health and livestock include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol. Mycotoxins appear in the food chain as a result of mould infection of crops both before and after harvest. Exposure to mycotoxins can happen either directly by eating infected food or indirectly from animals that are fed contaminated feed, in particular from milk (WHO, 2018).

Since food grain losses that ranges between 25–40% is incurred in Sub-Saharan Africa, which mostly occur during storage at the farm level (Adesina *et al*., 2019).This research work therefore, aims to determine the degree of mycotoxin contamination of sorghum grains in three ecological niches in study area, using the HPLC/MS/MS technique/approach.

MATERIALS AND METHODS

Survey Site

Surveys were conducted in the extensively Sorghum producing areas of the of the Northern guinea savannah (NGS). The NGS lies within latitudes 9°10′ and 11°59′ N and longitudes 3°19′ and 13°37′ E and has a unimodal rainfall distribution averaging between from 900 mm to 1000 mm annually, and maximum temperatures varying from 28 °C to 40 °C (Sowunmi and Akintola, 2010). Across the region, temperatures increase and rainfall decreases with increasing latitude. (Atehnkeng *et al.*, 2008).

Sampling

This was based on the method of Atehnkeng *et al.*, (2008) with some modifications. Briefly, purposive sampling was carried out in five (5) randomly selected communities from the NGS, agro-ecological zone, identified to subsist on sorghum as a major source of their di*et al*most on daily basis namely: Babanna, Kontagora, Birnin Gwari, Sabuwa, and Maiduguri. The selected communities were tagged “districts” and five surrounding villages “locations” that are at least 20 Km away from each other were also selected from the districts for the purpose of sample collection. In each district, Sorghum grains in stores, market and bunches in the field were sampled from the five locations. At each location, a single farmer who grew sorghum in the previous season was identified and 1kg of sorghum with or without visible signs of fungal growth was arbitrarily selected from the farmer's store. Only Sorghum that had been in storage for up to 2 months were sampled from each farmer during the survey. This duration is long enough for mycotoxin to accumulate in fungi infected Sorghum grains (Sauer and Tuite, 1987; Olakojo and Akinlosotu 2004).

A total of 75 kg (i.e. [1 kg × five locations×five districts] x 3 eco-niches) were collected from the NGS zone. One hundred grams (100g) was taken from each kg in each of the locations and these 100g was ground into powdered form and used for aflatoxin (AF) Deoxynivalenol (DON), Zearalenone (ZEA), Fumonisin (FB) and Ochratoxin (OTA) analysis. To prevent further post-collection accumulation of moulds prior to analysis, all the samples were properly sealed and stored at 4^{o}C.

Extraction and Clean-Up Procedures

A multi-mycotoxin extraction method devised by Patterson and Roberts (Paterson and Roberts as employed by Makun *et al.* (2011), without modifications was employed for extractions of all the aflatoxins (AFs), zearalenone (ZEA), ocharatoxin (OTA), and deoxynivalenol (DON).

In the case of FB, extraction method of Sydenham *et al.* (1992), without modification was employed as thus: Sub sample (25 g) was mixed with 50 ml of methanol/water (3:1) in a volumetric flask and shaken for one hour and then filtered through Whatman No1 filter paper. The pH of the extract was adjusted to 6-6.5 using acetic acid (to enable the binding of the fumonisin on the SAX column). The SAX cartridge was first conditioned by washing with 5 ml methanol (MeOH) and 5 ml MeOH/H_2O (3:1v/v). The flow rate was maintained at 2 ml/min. The column was then washed with 5 ml of MeOH/H_2O (at 3:1v/v) and subsequently with 3 ml MeOH. The fumonisin (FB_1) was finally eluted at the flow rate of 1ml/min with 10 ml of 1% acetic acid in MeOH. The eluate was dried under the stream of nitrogen gas at 60°C and stored at 4 – 8°C until further analysis.

Mycotoxin Analysis

AFs (AFB1, AFB2, AFG1 and AFG2) were individually determined using HPLC with fluorescence detection after post column electrochemical derivatization with bromine using KOBRA cell (Reifand and Metzge, 1995). The eluent (Mobile phase) was water/methanol/Acetonitrile (60:20:20) v/v) with addition of 25 µL of Triflouroacetic acid (TFA) per litre at a flow-rate of 1.00 ml/min (isocratic). The AFs were detected using a scanning Photo diode array (PDA) detector (λex. = 365 nm, λem. = 500 nm). ZEA in its own case was analysed by fluorescent detector at excitation and emission wavelengths of 274 nm and 455 nm, respectively, in accordance with the method of Abdulkadar *et al*. (2004). The injection volume was set at 20 µl, while the mobile phase used was acetonitrile/water/Methanol, (46: 46: 8 v/v) was pumped at the rate of 1ml/min. OTA analysis was performed accordingly, by fluorescence detection as described by Ghali *et al.* (2009), and emission wavelengths of 333 nm and 443 nm was set and used. Residues for FB analysis were reconstituted in methanol and aliquots derivatized with o-phthaldialdehyde (OPA) prior to separation on a reversed-phase HPLC system using fluorescence detection at excitation and emission wavelengths of 335 and 440 nm respectively (Shephard *et al*., 2000). The isocratic mobile phase made up of 0.1mol/L sodium dihydrogen phosphate/methanol (80:20) that had its pH adjusted to 3.5 using Acetic acid, was pumped at a rate of 1 ml/min. DON was also analysed on a photodiode array detector (PDA) at 220 nm according to the method described by Igor *et al.* (2008). The mobile phase was Water/Methanol (85:15 v/v) and was pumped at a flow rate of 0.4 ml/min. The injection volume 20 µl. Mycotoxins were quantified using peak area and external calibration curves.

Validation of Mycotoxins Analytical Methods

In order to ensure reliability of the results, the typical parameters for validation methods such as: specificity, accuracy, linearity and detection limits as recommended by Araujo (2009) were used in addition to the ensuring that, validated methods and analytical grade reagents were employed in the course of the determination process.

RESULTS

Table 1 reveals the individual and mean aflatoxin B_1 concentration of samples from different location within the sampling districts in the NGS agro-ecological zones.

The mean fumonisin concentration as revealed in Table 2, indicates that field samples from the NGS had the highest mean value of 1890.0 µg/kg, storage samples from NGS (1636.8 µg/kg)).

The mean OTA concentration as revealed by Table 2 shows that, field samples from NGS had the highest concentration of 92.9 µg/kg while the market samples from NGS, storage samples from NGS have values of 88.7 and 66.9 µg/kg, respectively.

Table 1: Aflatoxins concentration ((µg/kg)) in the three eco-niches in the sampling locations of the NGS agro-ecological zones

Mycotoxins	Sample	Field	Store	Market
AFB_1	1	13.7	123.8	30.6
	2	0.00	0.00	19.2
	3	23.6	98.5	93.8
	4	95.2	420.6	151.9
	5	9.5	261.1	108.0
Mean AFB_1(µg/kg)		$28.4±2.47^a$	$180.8±23.45^c$	$80.7±16.86^b$
AFB_2	1	11.3	0.00	12.4
	2	4.4	78.4	0.00
	3	10,4	61.9	78.5
	4	87.9	31.3	32.1
	5	14.0	449.9	31.0
Mean AFB_2(µg/kg)		$25.6±2.65^a$	$124.3±27.36^c$	$30.8±5.30^b$
AFG_1	1	37.6	52.1	4.7
	2	46.0	68.3	3.6
	3	64.5	407.7	0.00
	4	94.5	0.00	84.4
	5	22.4	139.4	16.3
Mean AFG_1(µg/kg)		$44.6±6.21^c$	$133.5±21.11^f$	$21.8±4.01^a$
AFG_2	1	41.8	13.7	21.6
	2	62.0	0.00	70.0
	3	47.0	85.7	212.1
	4	23.4	30.8	76.3
	5	19.1	33.3	96.5
Mean AFG2(µg/kg)		$38.6±7.22^b$	$32.7±2.89^a$	$95.3±8.33^c$
TOTAL AFs(µg/kg)		$137.2±26.73^a$	$471.3±82.13^c$	$228.6±34.4^b$

Values are Mean ± SEM of triplicate determinations. Values with different superscripts across the row are significantly different ($p \leq 0.05$)

Table 2: Other mycotoxins concentration ((µg/kg)) in the three eco-niches in the sampling locations of the NGS agro-ecological zones

Mycotoxins	Sample	Field	Store	Market
FB_1	1	1910.0	1450.8	1530.0
	2	2034.8	4924.0	1200.0
	3	1875.0	1660.0	177.0
	4	1869.6	32.1	1890.0
	5	1760.6c	117.1	620.0
Mean FB_1		1890.0 ± 23.7^c	1636.8 ± 28.3^b	1083.4 ± 15.3^a
OTA	1	0.00	0.00	0.00
	2	24.6	56.8	43.2
	3	20.9	146.2	350.4
	4	303.3	65.8	34.6
	5	115.7	65.7	15.8
Mean OTA		92.9 ± 4.2^c	66.9 ± 6.2^a	88.7 ± 8.4^b
ZEA	1	1031.0	210.3	689.0
	2	786.0	797.6	2605.4
	3	438.6	47.6	510.0
	4	3358.0	746.5	926.9
	5	346.4	0.00	896.2
Mean ZEA		1192.0 ± 19.6^c	360.4 ± 13.5^a	1125.5 ± 32.6^b
DON	1	320.4	456.4	4134.0
	2	4447.1	336.9	1320.4
	3	458.3	1081.0	532.8
	4	0.00	0.00	0.00
	5	446.7	1040.0	147.8
Mean DON		1711.2 ± 31.7^c	582.9 ± 9.5^a	1226.9 ± 19.7^b

Values are Mean ± SEM of triplicate determinations. Values with different superscripts across the row are significantly different ($p < 0.05$)

KEYS: AF = aflatoxins, FB= fumonisins, OTA= ochratoxin A, ZEA= zearalenone, DON= deoxynivalenol

KEY: Numbers 1- 5 stands for the names of the sampling locations in the NGS agro- ecological zone

S/No	NGS
1	Babanna
2	Kontagora
3	B/ Gwari
4	Sabuwa
5	Maiduguri

Numbers: 1-5 represents locations in northern guinea savannah (NGS)

Table 3: Mean mycotoxins concentrations (µg/kg) in sorghum samples from the three eco-nichs in the northern guinea savannah agro-ecological zone of Nigeria

Mycotoxins (µg/kg)	Field	Store	Market
Mean AFB_1 (µg/kg)	28.40± 2.47^a	180.80± 23.45^c	80.70± 16.86^b
Mean AFB_2 (µg/kg)	25.60± 2.65^a	124.30± 27.36^c	30.80± 5.30^b
Mean AFG_1(µg/kg)	44.60± 6.21^b	133.50± 21.11^c	21.80± 4.01^a
Mean AFG_2 (µg/kg)	38.60± 7.22^b	32.70± 2.89^a	95.30± 8.33^c
Total AFs (µg/kg)	137.20± 26.73^a	471.30± 82.13^c	228.60± 34.80^b
Mean OTA (µg/kg)	92.93± 3.20^b	66.90± 4.3^a	88.75± 3.20^b
Mean FB_1 (µg/kg)	1890.00± 34.20^c	1636.80± 17.00^b	1083.40± 21.00^a
Mean Zea (µg/kg)	1192.00± 11.40^c	360.40± 12.40^a	1125.50± 26.00^b
Mean DON (µg/kg)	1134.50± 23.45^b	583.00± 10.70^a	1227.00± 25.00^c

Values are Mean ± SEM of triplicate determinations. Values with different superscripts across the row are significantly different ($p < 0.05$)

KEY: AF = aflatoxins, FB= fumonisins, OTA= ochratoxin A, ZEA= zearalenone, DON= deoxynivalenol

DISCUSSION

Taking into account, the high concentration of aflatoxins on the grain samples from the three eco-niches in the NGS (Table 1). It suffices to say that a serious health crisis (e.g. HCC) is in existence but probably un-noticed, due to poor or low awareness on the existence and health implication of these mycotoxins. Since a healthy individual is more able to fight the toxins than the one that is malnourished or diseased, the deg7uhyuree of health challenges encountered in the study area is certainly at a worrisome level, due to the fact that the level of poverty in the studied area is an issue to reckon with.

The concentration of AFB1, B2, G1 and G2 was found to be higher in the in the stored sample across all the sampling locations of the study area. The dependence on environmental or extrinsic factors such as such as relative humidity, temperature, and oxygen coupled with intrinsic factors, such as ingredient composition, pH, grain moisture, and water activity, for mould growth and subsequent mycotoxin production; a condition, that is commonly encountered in such eco-niche contributed to greater extent the observations made. Based on a study conducted in 2002, the developing countries of south-eastern Asia and sub-Saharan Africa harbours an estimated 82% of all liver cancers occurring. Persons with chronic hepatitis B virus infection and to lesser extent patients with chronic hepatitis C virus infection constitute the majority of the HCC patients. (Okonkwo *et al*., 2016). The potential contributory factor to this menace in this region include high dietary exposure to aflatoxin, a common contaminant of foodstuffs such as nuts, grains and legumes which are the most commonly consumed food substances in the study area. Yang *et al* (2010) had noted that in resource poor countries such as Nigeria, effort at curbing the menace of HCC should be focused on prevention and adequate treatment of persons chronically infected with hepatitis B virus. Based on this note, the prevention of HCC in the northern guinea savannah region would probably be difficult for the fact that poverty has rendered most of the populace zone malnourished and diseased and hence lack the immune-competency to fight the toxins. However, this trend could be reversed with concerted mitigation and awareness strategies. The fact is, preventing mould and mycotoxin contamination is almost impossible; it is necessary for producers to implement a comprehensive mycotoxin management program to moderate these risks along the sorghum used for both animal feed and human food supply chain in an HACCP perspective. (Fumagalli *et al*., 2021).

Recently conducted survey performed to assess the worldwide incidence of mycotoxin contamination in food, feed and raw feed materials, mainly grains and grains co-products revealed that AFs, DON, FUM, ochratoxin A (OTA), T-2 toxin, and ZEN are the principal contaminating mycotoxins in food and feed (Gruber-Dorninger *et al*., 2019). Worthy of consideration from the results of the mycotoxin surveys is bringing to fore, two critical issues of great concern for food and feed safety: mycotoxin co-occurrence, modified and emerging mycotoxins (Rychlik et *al*. 2014).

As revealed in Table 2, just as in the case of AFs, the mean concentration of other mycotoxins such as FUM, DON, ZEN and OTA is above the above the maximum limits set by the regulatory agencies such as EFSA, (2020) and FAO/WHO (Codex Alimentarius) (2009). This high level coupled with the co-occurrence of the mycotoxins in the samples portends dangers of exposing the consumers of food and feeds produced from this grain, dangers/diseases associated with the consumption of these mycotoxins. The fact is, it is extremely difficult to encounter only one mycotoxin contaminating raw materials or grain. Worldwide, the incidence of co-contamination has been observed to be high. The global monitoring conducted by Streit *et al*. (2013), reported that 72% of the samples of feed and raw materials studied were contaminated with more than one mycotoxin. Also, 7 to 69 mycotoxins have been reported to be detected in 83 of the 169 samples analysed by Streit *et al*. (2013). The issue of co-contamination by mycotoxins in grains widely consumed in this part of the world is a great concern, as it may exert adverse effects on both humans that consume the grain, and/or grain products as food and the animals whose feed is sourced directly from the grain or its by-products (Fumagalli *et al*., 2021). This disturbing scenario may be due to the additive/synergistic interactions of the mycotoxins, the complexity of which varies according to the animal species, the level and type of mycotoxin contamination, the toxicity of the compound ingested, body weight, age and animal physiological condition, compound action mechanism, the presence of other mycotoxins, and the length of exposure (Pedrosa, 2010; Wan *et al*., 2013). Because Sorghum are staple grains that are cheaper, and with the current scarcity of food, disasters and poverty in the North Western Nigeria that the study area forms a substantial part, leave many people in this region of the world with little or no option but to purchase and consume low grade cereals. The consumption of contaminated grains by man and animals has severe consequences on public health particularly that the mycotoxins are found at unsafe levels (Makun *et al*., 2009).

When the mean concentration of the mycotoxins is considered (Table 3), it is clear that unless an emergency mitigation strategy is put in place, there is potent health crisis not only within the studied zone but across the country. This is due to the fact that as a result of the continuous movement of grains and food stuffs within and between different regions of the country (Nigeria), and in most cases involving even, trans-Saharan movement of these grains, possible outbreak of diseases associated with consumption of these mycotoxins either in the short or long term cannot be averted.

According to the World Health Organisation, food safety collaborative flatform, (2018), the effects of some food-borne mycotoxins are acute with symptoms of severe illness appearing quickly after consumption of food products contaminated with mycotoxins. Other mycotoxins occurring in food have been linked to long-term effects on health, including the induction of cancers and immune deficiency. Out of the several hundred mycotoxins identified so far, the AFs, OTA, FB,ZEN and DON have gained the most attention due to their severe effects on human health and their occurrences in food, and therefore calls for decisive action to mitigate the problems, in order to avoid the existing situation and the anticipated looming dangers.

The high concentration of mycotoxins (above the limits set by regulatory agencies) determined in the sorghum grains in this study, calls for urgent adoption of mitigation measures by both government and non-governmental organisations with a view to safeguard the health of the populace and improve on the competitiveness of our grain products in the international market, thereby, improving on the country's balance of trade with international partners.

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SCREENING F_1 ADVANCED SWEETPOTATO (*Ipomoea batatas* (L) LAM) SEGREGATING POPULATIONS FOR EARLY BULKING, DRY MATTER CONTENT AND OPTIMUM HARVESTING TIME IN UMUDIKE, SOUTHEASTERN NIGERIA

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ABSTRACT

Sweetpotato is an important carbohydrate root crop grown mainly for its storage roots for processing into various sweetpotato products due to its dry matter content. As a result a study of 23 sweetpotato genotypes was conducted at the Western experimental field of NRCRI, Umudike in 2020 and 2021 to select potential early storage root bulking and maturing genotypes with high dry matter content for early cultivation genotypes, to have information on precise time for harvesting each genotype, to select genotypes for extra-early, early, medium and late maturing for various end users. The experiment was laid out in a randomized complete block design with three replications. Each plot measured 4 x 3 m and comprised 4 ridges. Ten genotypes were used as samples per plot per genotype. The sweetpotato seed were cut 25 cm long, with at least 4 nodes. Which were inserted two nodes on the crest of the ridges in a slanting position and spaced 1m between ridges and 0.3m apart along the row on the ridges. Ten sweetpotato plants per plot were harvested at the interval of 4 weeks after planting (WAP). Plant attributes studied were number of marketable roots at 8, 12, 16 and 20 weeks after planting and number of unmarketable roots. The yield data were subjected to analysis of variance and their means separated with standard error of difference at the probability level of 0.05. Four harvest dates for the sweetpotato genotypes were proposed. Very early maturing, early maturing, intermediate and late maturing. The proposed dates were: 8, 12, 16 and 20 Weeks after Planting (WAP). Standard error of difference was used to assign genotypes to a harvest group/date. Results obtained indicated that Sweetpotato genotypes vary remarkably in their marketable root bulking and maturity dates. Harvesting at 8WAP would render the storage roots immature and unmarketable. Some genotypes required more than 16WAP to reach maturity. It is recommended that harvesting should be at 16 WAP. Assigning genotypes to a given harvest date is important for areas of short growing seasons as a result of short rainfall, areas of high disease infestation, areas with high market demand, for industrial uses and depends on type of utility of the storage roots. Genotype with dry matter of 28% is acceptable to most consumers.

Keyword: Sweetpotato, bulking, harvest date, dry matter and marketable roots

INTRODUCTION

Sweet potato [*Ipomoea batatas* (L.) Lam] is cultivated in more than 100 countries of the world. (FAOSTAT, 2014) observed that sweet potato is an important carbohydrate root crop grown as annual although could be perennial where the soil is very fertile. World sweet potato production in 2020 was 89,487,835 tons under total area of 7,400,472 hectares. In the year 2022 under review, FAOSTAT (2022) reported that the continent of Asia was the largest producer of the crop which accounted for 62.6%. This was followed by the continent of Africa with 32.2% while rest of the world produced 5.2%. In Africa, Nigeria was the largest sweet potato producer (3,867,871 tons). In Nigeria, Sweet potato regarded as food security crop. Despite the crops nutritional and health benefit, it ranked fifth after rice, wheat, maize, and cassava (Thottappilly and Loebenstein, 2009; Woolfe, 1991).

Sweet potato is seriously affected by water deficit especially during vine establishment and storage root bulking. This contributes to yield losses, yield gaps, poor quality planting material as a result of poor vine production, high infestation to pests and diseases, and poor absorption of soil nutrients (Gasura *et al.*, 2010). Low *et al (*2020) analyzed factors contributing to sweet potato yield gaps in Sub-Sahara Africa and found that the most yield limiting factor was lack of rainfall distribution during the growing period resulting into yield gap at the average root yields of 8.0 t/ha and 7.5 t/ha for East and South Africa respectively and 3.0 t/ha for West Africa (FAOSTAT, 2019). Although these figures are far below sweet potato yield potential of 35t/ha in Research stations, the major factor is genetic yield potential and timely bulking to escape drought period and during drought.

The current research efforts is geared towards developing not only high yielders but also rapid storage root bulking and early maturing types, high starch content genotypes. The early maturing types produce yields of high tonnage. The number of storage roots as well as earliness of root bulking and maturity may depend on the genotype, assimilate supply, photoperiod, and temperature (Maini, *et al.*, 1977). The process of tuberous root formation and maturity may also depend on soil water supply, soil fertility and soil temperature (Ikpi *et al.*, 1986).

Storage root maturity is characterized by leaf area decline and a slow rate of storage root bulking/growth. This phase may not occur in the field when medium or late maturing genotypes is grown in a short season. Early season storage root initiation and bulking or growth are acceptable for production in areas where sweetpotatoes are harvested prior to physiological maturity.

Environmental factors influence storage root bulking. For example, storage root bulking is best promoted by short photoperiods, high light intensity and cool climates, the meteorological factors influencing this process at a given location are basically air and soil temperatures, solar radiation, photoperiod, soil moisture, and crop water use (Githunguri, 2004). According to Nnodu *et al.* (2006) sensitivity to environmental conditions varies between genotypes. The most limiting environmental factors for sweetpotato production are heat and water stresses. Higher temperatures favor above ground biomass development and delay storage root initiation. Leaf senescence is also shortened by high temperatures, especially greater than 30°C as Maini *et al* (1977) reported. Heat stress leads to a higher number of smaller storage roots per plant and reduced dry matter content.

Drought stress limits vine growth and reduces the number of storage roots in larger size categories. Breeding genotypes must be suited to the cropping systems and growing season of a particular region within their agro-ecological area of adaptation. Base on this, storage root bulking information of genotypes at an advanced stage of selection is of great interest for recommendation for testing toward final adoption. Farmers prefer sweetpotato varieties which have high yielding and early maturing capacity. The desired attributes of a good early sweetpotato types are early storage rooting, rapid storage root bulking and short maturity period coupled with high starch accumulation within a short period before the onset of dry season, good in-ground storability, and good cooking qualities (Nnodu *et al.,* 2006). Early storage root bulking keeps pace with crop growth rate. Too early harvest of the sweetpotato crop often leads to reduction in storage root yield, while delayed harvest causes development of fibrous, weevil infested storage roots, reduction in starch content and deterioration of root quality (Ntawuruhunga *et al.,* 1998). Dry matter content is a function of yield, starch content and carbohydrate value of the sweetpotato crop, the assessment of the storage root dry matter content under the different harvesting dates will add impetus as to the best time of harvest. Many factors influence the maturity period of sweetpotato however, these factors varied as per each genotype. The optimum stage of harvest depends on varieties and ecological factors. It was considered desirable to determine the influence of different stages of growth, storage root yield and yield related traits with a view to defining the optimum harvest time for some genotypes. This study aims at selection of potential early storage root bulking and maturing genotypes with high dry matter content for early cultivation genotypes and to have information on precise time for harvesting each genotype and to select genotypes for extra-early, early, medium and late maturing for various end users.

MATERIALS AND METHODS

Study Site and Experiment Details

The experiments were conducted in 2020 and 2021 cropping seasons at Umudike Umuahia Abia State, Nigeria. Umudike is located within latitude 05°17' and 05°27' North and longitude 05°29' and 07°32' East of the Greenwich Meridian at altitude 122 m above sea level (NRCRI Metrology Unit, 2021). It lies in high rainfall forest area of over 2500 mm per annum, with mean photoperiod of 5 hours per day. The temperature is generally high, ranging from 27 to 34°C throughout the year. The average relative humidity is about 76%, with the lowest and highest values in January/December and July, respectively. The soil is typical Ultisols of acid sandy loam soil.
The trials were conducted at the Western experimental field of NRCRI, Umudike for assessing storage root bulking maturity of 23 sweetpotato genotypes. The site for the experiment was cleared and ridges constructed and spaced 1 m apart. The experiment was laid out in a randomized complete block design with three replications.

The 23 plots were replicated 3 times which gave a total of 69 plots, each plot measured 4 x 3 m and comprised 4 ridges. Twenty-five sweetpotato genotypes were used for the experiment. Ten genotypes were used as samples per plot per genotype. The sweetpotato seed vines were cut 25 cm long, with at least 4 nodes. The seed vines were inserted two nodes° on the crest of the ridges in a slanting position and placed 1m between ridges and 0.3m apart along the row on the ridges. Thirty plants per plot, equivalent to 33,333 plants per hectare. The seed vines were treated with Decis EC 12 by dipping and spread under shade for one hour before planting, against soil inhabiting pests, especially termites and weevils which attack sweetpotato seed vines in the field. Weeding was manually done three times, using the West African hoe and hand pulling. Cross bars /ridge ties were constructed to control erosion and conserve soil moisture.

Data Collection and Analysis

Ten sweetpotato plants from each plot were randomly selected and tagged for harvesting and data collection. Ten sweetpotato plants per plot were harvested at the interval of 4 weeks after planting (WAP). Plant attributes studied were number of marketable roots (that is storage roots with diameter of 4cm or weighed 100 g) at 8, 12, 16 and 20 weeks after planting and number of unmarketable roots (that is storage roots with diameter less than 4cm or weighed less than 100g). The yield data were subjected to analysis of variance and their means separated with standard error of difference at the probability level of 0.05. Four harvest dates for the sweetpotato genotypes were proposed.

Very early maturing, early maturing, Intermediate and late maturing. The proposed dates were: 8, 12, 16 and 20 Weeks After Planting (WAP).

From the Ten plants that were selected randomly from each plot, data on dry matter parameters were recorded during the period of the experiment such as dry matter weight of storage roots harvested at different WAP. The root samples were oven dried at 72 °C temperature and calculated as

Dry matter content of marketable root = <u>weight of Oven dried marketable roots</u>
Fresh weight of marketable roots

Statistical Analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using statistical computer software. Data collected in respect of each maturity group were first computed with analysis of variance (ANOVA) separately before a combined ANOVA across maturity groups and the two years growing seasons using PROC GLM model of SAS (SAS Institute, 2007) was computed to determine mean squares for each character. The degree of statistical difference was determined using probability levels P<0.01 and P< 0.05. Differences in character means were also measured using Standard error of difference means.

Evaluation Parameters: Data Collected At Harvest Included Marketable Root Size

Separate marketable roots i.e., those ≥ 4 cm in diameter (>100 g). The percentage of marketable roots and number of unmarketable roots were calculated: as those less than 4cm or less than 100g. At each harvest date 10 plants from each plot were harvested. Marketable root numbers were analyzed using analysis of variance (ANOVA). Means between harvest dates within test genotypes, and means between test genotypes at each harvest date are compared using standard error of difference.

Data Interpretation

The Storage root bulking stage is a key determinant of the marketable component of total yield, characterized by a constant rate of increase in storage root size. Hence, performance of marketable storage root size across harvest date is of great importance in determining bulking maturity. To assign a test genotype to a given storage root bulking maturity grade, The genotype that did not perform statistically different for marketable storage root number across harvest date in the first harvest date can be regarded as early maturing. The genotypes that perform statistically better in the second harvest date though not significantly different to the third harvest date can be regarded as medium maturing. The genotypes that perform statistically better in the third harvest date can be regarded as late maturing. Genotypes that show no statistical difference in marketable storage root weight in two consecutive harvest dates may show a statistically significant increase in their marketable storage root yield. Since marketable storage root yield is a function of marketable storage root weight and number, a significant increase in marketable storage root yield can be attributed only to a greater number of marketable storage roots. This would be the case of sweetpotato genotypes that were able to produce additional storage roots during later stages of plant development or genotypes with more than one storage root setting cycle.

RESULTS

Distribution of Rainfall and Soil Analysis

During the cropping seasons of 2020 and 2021, there were adequate and evenly distribution of rains throughout the growing periods of May to October. In each of the growing year, there was a significant rainfall drop (August break) in August, 2020 and August 2021. The physico-chemical analysis of the soil of 0-15 and 15-30 cm soil depth indicated that the soil at the experimental site was comparable in both depths in both years. The particle size analysis of the soil type was sandy loam with a high proportion of sand (74.3%) but less clay (5.7%), silt (20.4%). The chemical characteristics of the soil showed that the soil was slightly acidic (pH of 6.5) with adequate cation exchange capacity (12.90 cmol kg-1). The total Nitrogen (0.6%), organic carbon (9.8%), calcium (2.5 cmol kg-1) and magnesium (2.4 cmol kg-1) values were low. There was a high concentration of available phosphorus (7.4 mg kg-1).

The result indicated high significant difference ($P<0.01$) for the number of marketable roots that bulked at 8WAP (Table 1). Very few storage roots of most genotype reached marketable size at 8WAP. This low number of marketable root yield recorded indicated that the storage roots were still bulking and had not reached maturity. The standard error of 2.0 for marketable roots at 8WAP led to lack of statistical differences among the sweetpotato genotypes for this trait despite the wide range of yield values of 0 to 2.2 with mean number of marketable root of 0.3. The standard error of difference indicated that all the genotypes were still in the same group of immaturity and were still bulking. The mean number of unmarketable roots at 8WAP was high compared to other harvest dates representing 99.9% of total storage roots produced at date. This indicated that the earlier harvest interrupted the bulking rate of the roots reducing the storage root size and render the storage roots unmarketable in all the test sweetpotato genotypes. It is likely that most of the genotypes require more number of weeks to bulk to marketable size. Hence, it is not recommended to harvest any of the test genotypes at this date of 8WAP.

Table 1 shows that most of the sweetpotato genotypes had at 12 WAP produced significantly ($P<0.01$) greater number of storage roots of marketable size than others. The number of marketable root ranged from 0 to 16 with mean marketable root number of 7.4 which accounted for 90.2% of total number of storage roots produced by the test genotypes. The standard error difference of 5.0 account for the statistical difference of the genotypes at harvest date of 8 WAP and 12 WAP. Forty-eight percent (48.0%) of the genotypes showed good number of marketable root size when harvested at 12 WAP. If harvesting was to be carried out, the sweetpotato genotypes that yielded more than the mean number of marketable roots of 7.4 and were grouped together by the standard error of difference would be selected. These genotypes should be harvested at 12 WAP and regarded as early maturing based on the proposed four harvest dates. The genotypes included: PO3/11, PO3/93, PO3/14,

PO3/119, PO3/38, NWA/OP/247, 87/OP/194, PO3/95, PO3/40, 87/OP/208 and NWA/OP/242. These sweetpotato genotypes should be of particular importance for areas of short growing seasons, where early harvesting is required, or areas for escape for disease and pests infestation or areas where the farmers require high produce turn-over as a result of high demand for storage roots for industrial raw material such as starch for flour.

At 16 WAP the genotypes yielded significantly better even though a few marketable roots were harvested, they were not significantly different from those harvested at 12 WAP. However, a significant greater number of marketable roots at 16 WAP indicated that bulking was still in progress while at 12 WAP for most of the genotypes and as such those genotypes could be regarded as intermediate/medium maturing genotypes. The marketable root size ranged from 0 to 13 with mean of 5.7 which accounted for 68.7% of total number of roots harvested while unmarketable root size number accounted for 31.3% of total number of storage roots harvested. This should be expected because some creeping sweetpotato genotypes continue to produce storage roots at the nodes that made contact with the soil. In contrast, no significant difference was observed for marketable number of roots across harvest dates of 12 WAP and 16 WAP.

This indicated that these genotypes could as well be regarded as both early and medium maturing under Umudike conditions. The genotypes grouped under this date yielded more than the general mean number of marketable root of 5.7. The genotypes belonging to this group accounted for 65% and were: NWA/OP/231, NWA/OP/242, PO3/903, 87/OP/194, PO3/95, PO3/40, 87/OP/208, NWA/OP/247, 87/OP/287, PO3/38, PO3/01/14, PO3/03, PO3/11 and 87/OP/210. Their marketable root yield were above the mean yield of 5.7 number of marketable root yield. These genotypes could be harvested piece meal whenever the need arises in the household.

At 20 WAP, few genotypes produced high significant ($P < 0.01$) mean number of marketable roots higher than the mean marketable root of 2.8 which accounted for 31.3% of the total storage root yield. This indicated that 3.9% of the genotypes could be late maturing. These genotypes were: 87/OP/145, PO3/903, PO3/95, PO3/119, PO3/11 and 87/OP/210. The standard error of difference placed them in late maturing group. The late maturing genotypes has an advantage over the early maturing ones as significantly higher marketable roots can be expected in a late harvest. This is important when farmers need to decide their harvest date according to the markets' demands and supply of sweetpotato roots. The medium/intermediate maturing sweetpotato genotypes such as NWA/OP/231 and PO3/01/14 had long senescence and died and could not survive up to 20 WAP.

Dry Matter Content

The result of the dry matter content in Table 1 in 2020 showed that dry matter content of the marketable bulked roots of the genotypes ranged from 0.0 to 11.0% with mean of 5.2%. The very low dry matter content of the marketable storage roots indicated that the storage roots at this stage were still bulking and very immature to be harvested at 8WAP. At 12 WAP, the dry matter content of the bulked marketable roots ranged from 10.0 to 28.0% with mean of 22.0%. The increased rate of dry matter content indicated that some of the genotypes that bulked could be harvested. Although these genotypes are orange fleshed varieties that have negative correlation with dry matter content. The dry matter content of 28.0% is acceptable to consumers. The storage roots could be used for various value additions by food processors. The genotypes harvested at 16 WAP had dry matter content that ranged from 0.0 to 28.0% with mean of 23.9%. At this harvest date, majority of the genotypes have reached their dry matter ceiling and could be harvested. The number of marketable roots at this stage could be acceptable for human and animal consumption. The genotypes harvested at 20 WAP in Table 1 showed that dry matter content ranged from 0 to 28.0% with mean of 24.9%. These genotypes with their marketable roots have reached ceiling point for dry matter accumulation and could be harvested else they will be lignified.

Number of marketable roots at 2021 vary significantly ($P<0.01$) among the genotypes in all the proposed dates. The result in Table 2 showed very few mean number of marketable of root of 0.4 at 8 weeks after planting which accounted for 2.8%. The mean number of unmarketable root represented 97.2% of the total roots produced. This suggested that the storage roots of most of the genotypes were still bulking and were not yet mature. The number of marketable roots obtained ranged from 0 to 2. The high standard error of difference of 0.64 for marketable root at 8 weeks after planting indicated no statistical difference among the genotypes which showed that they are still in the same group of storage root immaturity and still bulking and therefore cannot be harvested at this stage. Harvesting the storage roots at this stage is tantamount to destroying and wasting the crop.

At 12 WAP, the mean number of marketable roots was 5.4 which represented 33.8% while the mean number of unmarketable roots was 11.4 or 66.4% of the total number of storage roots produced. This result indicated that major part of the storage roots were still bulking and immature. The marketable root number ranged from 0 to 14. The standard of error of difference for the number of marketable root potential in the bulking account for statistical difference among the genotypes at 12 WAP. Some genotypes showed marketable root size when harvested at 12 WAP. However, 52% of the genotypes evaluated may be harvested at 12WAP as a result of producing 33.8% of marketable root yield.

At 16 WAP, mean marketable yield number was 11.3 which accounted for 75.2% of the total root yield while mean yield of unmarketable roots was 3.9 which represented 24.8%. The marketable root yield ranged from 0 to 18. At this stage, the genotypes yielded significantly better marketable roots potential. The statistical error of difference of 3.46 indicated significant difference means among the test genotypes. However significant differences was observed for number of marketable roots across harvest dates of 12 WAP and 16 WAP as shown by the standard error of difference. This group of genotypes could be assigned as medium maturing genotypes under Umudike agro-ecological condition. Forty-eight percent which yielded more than the grand mean fall under this group.

At 20 WAP yield of marketable roots varied significantly ($P<0.01$). It ranged from 2 to 10 with mean of 6.0 which accounted for 70.1% of total number of storage roots produced during this period. This showed that some genotypes were late maturing. The standard of error of difference of 2.52 grouped these genotypes under late maturing genotypes. Thirty-nine percent of the genotypes were under this group.

Dry Matter Content

The dry matter content (DMC) of the genotypes at 8 WAP in 2021 vary significantly (P<0.01) and ranged from 0.0 to 17.0% with mean of 17.3%. The low percentage DMC was as a result of immaturity of the bulking storage roots. The DMC was very low at this stage (Table 2). The result also indicated that at 12 WAP, the DMC appreciated significantly (P<0.01) and ranged from 0.0 to 29.0% with mean of 23.0%. At this stage, the rate of bulking and dry matter accumulation had increased. Genotypes with dry matter accumulation up to 28.0% could be harvested at this stage.

The DMC of the test genotypes at 16 WAP vary significantly (P<0.01) and ranged from 13.0 to 28.0% with mean of 27.1%. Most genotypes had increased percentage of dry matter at this stage and could be harvested for consumption. The high DMC is an indication of maturity and high starch content which conferred good taste to the storage root of the genotypes under test. In 20 WAP, there was high significant variability in DMC of the genotypes under evaluation. The DMC ranged from 18.0 to 29.0% with mean of 27.0%. Most genotypes had their dry matter ceiling at this stage and could be harvested for consumption (Table, 2).

The combined analysis for the two years indicated that number of marketable roots that bulked at 8 WAP ranged from 0.0 to 2.5 with mean of 0.45. This accounted for 3.3% of the number of total roots produced by the test genotypes. However, number of unmarketable roots ranged from 7.0 to 28.5 which accounted for 96.7% which indicated that number of unmarketable roots (small roots) are still high and at their immature stage. This suggested that the storage roots were still bulking. Harvesting at this stage is not ideal and is tantamount to wasting the developing storage roots. Almost all the test genotypes were still bulking at this stage.

The number of marketable roots at 12 WAP were highly significant (p<0.01) and ranged from 0.0 to 14.5 with mean of 6.4 roots which accounted for 52.0% of total roots produced by the test genotypes. This indicated that most genotypes produced roots that bulked at that date and that were marketable. The 48.0% of unmarketable roots indicated that there were roots in some genotypes that were still bulking. However, the standard error of 2.54 of marketable root size at 12WAP could be used to assign harvesting date to some genotypes at 12 WAP. Genotypes with number of marketable roots above the Check variety TIS87/007 of 7.0 could be assigned to be harvested at 12 WAP. These genotypes were: 87/OP/132 with (12.0 marketable roots (MR)), NWA/P/242 (10.5 MR), 87/OP/194 (14.5 MR), PO3/95 (12.0 MR), PO3/40 (10.0 MR), 87/OP/208 (12.5 MR), 87/OP/287 (14.0 MR), PO3/38 (8.5 MR), PO3/93 (9.0 MR) and PO3/11 (7.5 MR)

The combined analysis of the number of marketable roots at 16 WAP showed that number of marketable roots of the genotypes that bulked at that date ranged from 0.0 to 13.0 with mean of 8.9. The high percentage of bulked roots that were of marketable root size at that date indicated that most genotypes bulked at that date. However, standard error for assigning harvest date (SE 3.04) indicated that although majority of the genotypes had high rate of root bulking at that date they do not differ much from those harvested at 12 WAP.

This also indicated that genotypes harvested at 12 WAP could be harvested at 16 WAP and could be assigned as intermediate genotypes. The high percentage of genotypes with bulked roots that were marketable showed that it was the best harvest date for most genotypes.

Table 1: Number of Marketable roots and dry matter content of the sweetpotato genotypes at 8, 12, 16 and 20 weeks of harvesting in 2020 cropping season

	8 Weeks				12 Weeks				16 Weeks				20 Weeks				
Varietal Name	Market able roots	Un-market able roots	Total storage	% Dry matter content	Market able roots	Un-market able roots	Total storage	% Dry matter content	Market able roots	Un market able roots	Total storage	% Dry matter content	Market able roots	Un-market able roots	Total storage	%Dry matter content	Mean number of roots
87/OP/132	1	13	14	10.0	7	2	9	20.0	0	3	3	21.0	2	4	6	22.0	8.0
PO3/016	0	7	7	5.0	7	0	7	24.0	0	0	0	0.0	2	4	6	28.0	5.0
87/OP/145	0	9	9	7.0	2	0	2	15.0	6	0	6	23.0	5	2	7	24.0	6.0
NWA/OP/231	0	7	7	2.0	4	1	5	10.0	7	1	8	27.0	0	0	0	0.0	5.0
NWA/OP/242	0	19	19	11.0	13	0	13	27.0	8	0	8	27.0	1	3	4	28.0	11.0
PO3/903	0	14	14	3.0	6`	2	6	17.0	6	0	6	21.0	7	1	8	23.0	9..0
87/OP/194	0	26	26	10.0	15	2	17	27.0	13	6	19	28.0	8	3	11	27.0	54.0
PO3/95	1	31	32	11.0	16	2	18	28.0	11	4	15	28.0	8	10	18	26.0	21.0
PO3/40	0	29	29	2.0	15	0	15	22.0	8	4	12	26.0	1	3	4	27.0	15.0
87/OP/208	0	8	8	4.0	16	0	16	28.0	9	3	11	27.0	3	5	8	28.0	10.8
NWA/OP/247	0	36	36	6.0	8	1	9	18.0	12	8	20	28.0	1	8	9	29.0	19.0
87/OP/287	0	8	8	3.0	7	3	10	24.0	6	4	10	22.0	3	2	5	24.0	8.3
PO3/38	1	14	15	4.0	9	1	10	26.0	9	3	12	27.0	3	4	7	28.0	12.0
PO3/119	2	9	11	2.0	8	1	9	27.0	4	0	4	18.0	8	0	8	24.0	8.0
NWA/OP/28	0	0	0	0.0	0	0	0	0.0	0	6	6	19.0	1	0	1	22.0	2.0
PO3/82	0	12	12	4.0	0	0	0	0.0	0	1	1	10.0	1	1	2	17.0	3.8
MAX	0	12	12	3.0	2	0	2	16.0	3	1	4	24.0	1	4	5	27.0	5.8
PO3/01/14	2	7	9	6.0	8	3	11	27.0	12	3	15	28.0	0	0	0	27.0	9.3
PO3/93	0	14	14	3.0	11	4	15	28.0	10	4	14	27.0	0	2	2	28.0	11.3
NWA/OP/290	0	7	7	2.0	3	0	3	17.0	3	2	5	25.0	1	8	9	27.0	6.0
PO3/11	0	19	19	3.0	9	2	11	28.0	8	4	12	27.0	3	5	8	28.0	13.0
87/OP/210	0	15	15	2.0	7	3	10	27.0	8	6	14	27.0	9	8	17	28.0	43.3
TIS87/0087	0	5	5	6.0	4	2	6	22.0	0	3	3	29.0	2	1	3	31.0	4.3
Mean	0.3	14.0	15.1	5.2	7.4	1.2	8.2	22.0	5.7	2.7	8.3	23.9	2.8	3.1	5.9	24.9	11.6
Range	0-2	0-36	0-36	0.0-11.	0-16	0-4	0-18	10-28	0-13	0-8	0-20	0-28	0-9	0-10	0-18	0-28	2.0-54.
SE	2.2	3.8	=	=	5.0	2.0	=	=	1.0	3.0	=	=	3.2	2.1	=	=	=
%	0.02	99.9	=	=	90.2	9.8	=	=	68.7	31.3	=	=	47.5	52.5	=	=	=
Sig level	P<0.01	P<0.01	=	=	P<0.01	P<0.01	=	=	P<0.01	P<0.01	=	=	P<0.01	P<0.01	=	=	=

Table 2: Number of Marketable roots and dry matter content of the sweetpotato genotypes at 8, 12, 16 and 20 weeks harvested in 2021 cropping season

	8 Weeks				12 Weeks				16 Weeks				20 Weeks				
Varietal Name	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Mean number of roots across harvest dates
87/OP/132	1	8	9	12.0	5	12	17	21.0	10	6	16	25.0	7	4	11	23.0	13.0
PO3/016	0	4	4	5.0	5	13	18	25.0	13	0	13	27.0	6	4	10	28.0	11.0
87/OP/145	2	7	9	8.0	2	0	2	10.0	16	0	16	26.0	4	2	6	25.0	8.0
NWA/OP/231	0	10	10	12.0	2	12	14	18.0	17	1	18	27.0	1	1	2	18.0	11.0
NWA/OP/242	1	11	12	12.0	8	15	23	27.0	8	0	8	28.0	4	1	5	28.0	12.0
PO3/93	0	16	16	5.0	7`	18	25	27.0	6	0	6	23.0	9	2	11	26.0	15.0
87/OP/194	2	22	24	12.0	14	14	28	27.0	13	6	19	28.0	10	3	13	28.0	21.0
PO3/95	1	26	27	13.0	8	17	25	28.0	11	4	15	28.0	8	5	13	28.0	20.0
PO3/40	0	23	23	6.0	5	10	15	24.0	18	4	22	26.0	4	1	5	22.0	16.0
87/OP/208	0	11	11	14.0	9	11	20	28.0	9	3	11	27.0	5	5	10	28.0	13.0
NWA/OP/247	0	28	28	8.0	8	13	21	28.0	12	8	20	28.0	6	4	10	29.0	20.0
87/OP/287	0	12	12	4.0	7	23	20	28.0	16	4	20	27.0	4	2	6	25.0	15.0
PO3/38	0	16	16	5.0	8	11	19	27.0	9	3	12	27.0	7	4	11	28.0	15.0
PO3/119	1	13	14	17.0	8	14	22	27.0	14	0	14	28.0	9	1	10	23.0	15.0
NWA/OP/28	0	5	5	1.0	0	1	1	17.0	0	13	13	18.0	5	2	7	26.0	7.0
PO3/82	0	2	2	3.0	0	0	0	0.0	0	10	10	13.0	8	3	11	19.0	6.0
MAX	0	22	22	5.0	0	8	10	26.0	7	1	8	26.0	7	2	9	27.0	12.0
PO3/01/14	1	12	13	6.0	5	13	18	27.0	12	3	15	28.0	2	0	2	27.0	12.0
PO3/93	0	12	12	6.0	7	14	21	28.0	10	4	14	27.0	6	1	7	28.0	14.0
NWA/OP/290	0	10	10	4.0	0	6	6	22.0	12	6	18	26.0	8	3	11	27.0	11.0
PO3/11	0	21	21	6.0	6	12	18	28.0	18	4	22	27.0	4	5	9	28.0	18.0
87/OP/210	0	18	18	4.0	6	13	19	27.0	16	6	22	27.0	10	3	13	27.0	18.0
TIS87/0087	0	10	10	5.0	4	12	16	29.0	18	3	21	29.0	6	3	9	32.0	14.0
Mean	0.4	14.0	14.0	7.3	5.0	11.0	16.0	23.0	12.0	4.0	15.0	27.1	6.0	3.0	9.0	27.0	13.0
Range	0-2	2- 28	2-28	0-17.	0-14	1-23	0-28	0-29	0-18	0-8	1-22	13-28	2-10	0-5	2-13	18-29	6.0-21.0
SE	0.64	3.82	=	=	2.32	3.44	=	=	3.46	2.02	=	=	2.52	1.61	=	=	=
%	2.8	97.2	=	=	33.8	66.2	=	=	75.2	24.8	=	=	70.1	29.9	=	=	=
Sig. level	P<0.01	P<0.01			P<0.01	P<0.01			P<0.01	P<0.01			P<0.01	P<0.01			

Table 3: Combined analysis of the Number of Marketable roots and Dry matter content of the sweetpotato genotypes harvested at 8, 12, 16 and 20 weeks after planting in 2020 and 2021 cropping season

	8 Weeks				12 Weeks				16 Weeks				20 Weeks				
Varietal Name	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Marketable roots	Unmarketable roots	Total storage	% Dry matter content	Mean number of roots across harvest dates
87/OP/132	1.0	10.5	11.5	10.5	12.0	7.0	19.0	20.5	5.0	4.5	9.5	23.0	4.5	4.0	8.5	22.5	10.5
PO3/016	0.0	8.0	8.0	5.0	0.0	5.5	5.5	24.5	6.5	0.0	6.5	13.5	4.0	4.0	8.0	28.0	8.0
87/OP/145	1.0	8.5	9.0	7.5	2.0	6.5	8.5	12.5	11.0	0.0	11.0	24.5	4.5	2.0	6.5	24.5	7.0
NWA/OP/231	0.0	15.0	8.5	7.0	2.0	5.5	7.5	14.0	12.0	1.0	13.0	27.0	0.5	0.5	1.0	12.5	8.0
NWA/OP/242	0.5	15.0	15.5	11.5	10.5	7.5	18.0	27.0	8.0	0.0	8.0	27.5	2.5	2.0	4.5	23.0	11.5
PO3/93	0.0	24.0	15.0	4.0	6.5	10.0	16.5	22.0	6.0	0.0	6.0	22.0	8.0	1.5	9.5	25.5	12.0
87/OP/194	2.0	28.5	26.0	11.5	14.5	8.0	22.5	27.0	13.0	6.0	19.0	28.0	9.0	3.0	12.0	26.5	37.5
PO3/95	2.0	26.0	30.5	12.0	12.0	9.5	21.5	28.0	11.0	4.0	15.0	28.0	8.0	7.5	15.5	27.0	20.5
PO3/40	0.0	9.5	26.0	4.0	10.0	5.0	15,0	23.0	13.0	4.0	17.0	26.0	2.5	2.0	4.5	27.5	15.5
87/OP/208	0.0	32.0	9.5	7.0	12.5	5.5	18.0	28.0	9.0	3.0	12.0	27.0	4.0	5.0	9.0	25.0	11.9
NWA/OP/247	0.0	10.0	32.0	7.0	4.0	7.0	11.0	23.0	12.0	8.0	20.0	28.0	3.5	6.0	9.5	28.5	19.5
87/OP/287	0.0	15.0	10.0	3.5	14.0	13.0	27.0	26.0	11.0	4.0	15.0	27.0	3.5	2.0	5.5	26.5	11.7
PO3/38	1.5	11.0	16.5	4.5	8.5	6.0	14.5	26.5	9.0	3.0	12.0	27.0	5.0	4.0	9.0	26.5	13.5
PO3/119	1.5	2.5	12.5	9.5	4.5	7.5	12.0	27.0	9.0	0.0	9.0	23.0	8.5	0.5	9.0	26.0	11.5
NWA/OP/28	0.0	7.0	2.5	0.5	0.0	0.5	0.5	8.5	0.0	6.5	6.5	18.5	3.0	1.0	4.0	22.5	4.5
PO3/82	0.0	17.0	7.0	3.5	0.0	0.0	0.0	0.0	0.0	5.5	5.5	12.5	3.5	2.0	6.5	21.5	4.9
MAX	0.0	9.5	17.0	4.0	1.0	4.0	5.0	21.0	5.0	1.0	6.0	25.0	4.0	3.0	7.0	27.0	9.4
PO3/01/14	1.5	13.0	11.0	6.0	6.5	8.0	14.5	27.0	12.0	3.0	15.0	28.0	1.0	0.0	1.0	27.0	10.7
PO3/93	0.0	8.5	13.0	4.5	9.0	9.0	18.0	28.0	10.0	4.0	14.0	27.0	3.0	1.5	4.5	28.0	12.7
NWA/OP/290	0.0	18.5	8.5	3.0	1.5	3.0	4.5	19.5	7.5	4.0	11.5	25.5	3.5	5.5	10.0	27.0	8.5
PO3/11	0.0	18.5	18.5	4.5	7.5	7.0	14.5	28.0	13.0	4.0	17.0	27.0	3.5	5.0	8.5	28.0	15.5
87/OP/210	0.0	16.5	16.5	3.0	3.5	8.0	14,5	27.0	12.0	6.0	18.0	27.0	9.5	5.5	15.0	27.5	30.7
TIS87/0087	0.0	7.5	7.5	5.5	7.0	7.0	11.0	25.5	9.0	12.0	21.0	29.0	4.0	2.0	6.0	31.5	9.2
Mean	0.45	13.4	13.6	6.2	6.4	6.5	12.9	22.3	8.9	3.35	12.21	24.8	6.4	3.05	7.45	25.6	12.3
Range	0-2	7-28.5	7-32	3- 12	0-14.5	0-14.5	0-0.0	0-28	0-13	0-12	6.5-21	12.5-28	1-9.5	0-7.5	1-15.0	12.5-28	4.5-37.5
SE	0.68	3.74	=	=	2.54	2.52	=	=	3.04	1.87	=	=	2.87	1.77	=	=	=
%	3.3	96.7	=	=	49.0	51.0	=	=	72.8	27.2	=	=	59.0	41.0	=	=	=
Sig level	P<.01	P<.01	=	=	P<0.01	P<.01	=	=	P<.01	P<.01	=	=	P<.01	P<.01	=	=	=

The genotypes that could be assigned this harvest date were superior to the check variety TIS87/0087 with mean marketable bulked root of 9.0 marketable root (MR) include: 87/OP/145 (11.0 MR), NWA/OP/231 (12.0 MR), 87/OP/194 (13.0 MR), PO3/95 (11.0 MR), PO3/40 (13.0 MR), NWA/OP/247 (12.0 MR), 87/OP/287 (11.0 MR), PO3/01/14 (12.0 MR), PO3/93 (10.0 MR), PO3/11 (13.0 MR) and 87/OP/210 (12.0 MR).

At 20WAP, the test genotypes produced bulked roots that were marketable that significantly ($p<0.01$) ranged from 1.0 to 9.5 with mean of 4.4 which represented 59.0%. Majority of the test genotypes had high number of bulked roots that were marketable. The number of unmarketable roots which accounted for 41.0% showed that some genotypes were creeping types and were producing small roots at the nodes that were not yet bulked as to attend marketable root size as at that date. The standard error of 2.87 that was used to assigned harvest date to the two harvesting dates indicated that some genotypes could be harvested at 20 WAP and were regarded as late maturing. The late maturing genotypes were further selected based on their performance above the check variety TIS87/0087 which had mean of 6.5 marketable root size. The late maturing genotypes were: PO3/903 (8.0 MR), 87/OP/194 (9.0 MR), PO3/95 (8.0 MR), PO3/119 (8.5 MR) and 87/OP/210 (9.5).

Dry Matter Content

The combined analysis indicated high significant ($P<0.01$) variation in DMC for all the proposed harvest dates. The DMC at 8 WAP showed that the low percentage of DMC of the genotypes at 8WAP was as a result of storage root immaturity. The DMC ranged from 3.0 to 12.0% which showed that the DMC is very low due to low dry matter accumulation at that 8 WAP harvest date. There was increase in DMC accumulation as at 12 WAP. The dry matter accumulation ranged from 0.0 to 28.0% with mean of 22.3%. This showed that most genotypes could be harvested at the proposed harvest date of 12 WAP. The genotypes harvested at 16 WAP had DMC which ranged from 12.5% to 28.0% with mean of 24.8%. At this stage, most genotypes could be harvested for human consumption and for other value additions.

At 20 WAP, the mean DMC was 25.6%. This ranged from 12.5 to 28.0%. This indicated that DMC accumulation of the marketable roots have reached it ceiling for most genotypes. Those genotypes with high dry matter content of 27 to 28.0% could be harvested for human consumption, as article for commerce or for other value additions.

DISCUSSION

The high number of unmarketable roots at 8 WAP compared to other harvest dates of total storage roots produced indicated that the earlier harvest interrupted the bulking rate of the roots thereby reducing the storage root size and render the storage roots unmarketable in all the test sweetpotato genotypes. This also showed that most of the genotypes require more number of weeks to bulk to marketable size. It is not recommended to harvest any of the test genotypes at this date. The high standard error of difference indicated no statistical difference among the genotypes which showed that they are still in the same group of storage root immaturity and still bulking and therefore cannot be harvested at this stage. Harvesting at this stage destroys the storage roots.

Some genotypes showed marketable root size when harvested at 12 WAP. These sweetpotato genotypes should be of particular importance for areas of short growing seasons, where early harvesting is required, or areas for escape for disease and pests infestation or areas where the farmers require high produce turn-over as a result of high demand for storage roots for industrial raw material such as starch for flour.

At 16 WAP the genotypes yielded significantly better. They were not significantly different from those harvested at 12 WAP. However, a significant greater number of genotypes had bulked roots of marketable size at 16 WAP. This genotypes could be regarded as intermediate/medium maturing genotypes However significant differences was observed for number of marketable roots across harvest dates of 12 WAP and 16 WAP as shown by the standard error of difference. This group of genotypes could be assigned as medium maturing genotypes under Umudike agro-ecological condition. Forty-eight percent which yielded more than the grand mean fall under this group.

This indicated that these genotypes could as well be regarded as both early and medium maturing under Umudike conditions. According to Onyema (2008) sweetpotato is a tropical crop that is adapted to well drained sandy clay loam soil and has a short maturity period of 12 to 16 WAP with an average yield of 5.7 to 7.0 t/ha. However, not all sweetpotato genotypes mature within this period. Most genotypes mature earlier and later than this period. Maturity in this sense is when the storage roots bulked up to marketable size which is 100g and above or 4 cm in diameter and above.

At 20 WAP, few genotypes produced high significant ($P<0.01$) mean number of marketable roots yield. This indicated that most genotypes could be late maturing. The standard error of difference placed these genotypes in late maturing group. The late maturing genotypes has an advantage over the early maturing ones as significantly higher marketable roots can be expected in a late harvest. This is important when farmers need to decide their harvest date according to the markets' demands and supply of sweetpotato roots.

The duration and rate of storage root bulking in the sweetpotato plant determines the yield of the crop. The rate of storage root bulking describe the increase in storage root weight with time, while storage root bulking duration is the time between storage root initiation and persistence of the sweetpotato leaves. The decline in leaf area by senescence is as a result of the ceiling in storage root bulking. Although some sweetpotato genotypes does not senescence their leaves throughout their growing period. Sweetpotato genotype which is still bulking exhibit profuse exudates of sap from crack of storage roots. This factor account for yield differences between genotypes. However, storage root bulking duration is of greater importance as it seems to determine the final yield of sweetpotato crop. Storage root bulking results from two basic processes which include storage root initiation and storage root growth. These two factors is also affected by timing, duration, location, environmental factors, and genetic make-up of the individual genotypes.

However, genotypes of medium or late bulking maturity can be recommended for an earlier harvest date provided that the genotype is among those with best marketable storage root weight and yield at the referred date. Therefore, a comparison test between genotypes at a given harvest date is of paramount importance for a final recommendation of the genotype's harvest date. This is of particular importance for areas of short growing seasons, where early harvesting is required. The varietal responses in storage root bulking, harvest dates and dry matter accumulation and ceiling depended on inherent genetic potential of the sweetpotato genotypes. Sweetpotato genotypes could be improved to mature extra early or medium maturing through breeding which could lead to shortening of longer leaf life, increase leaf area and leaf area ratio.

The dry matter content (DMC) at 8 WAP showed low percentage of DMC. This was as a result of storage root immaturity. The DMC accumulation increased at 1 WAP. The dry matter accumulation ranged from 0.0 to 28.0% with mean of 22.3%. This showed that most genotypes could be harvested at the proposed harvest date of 12 WAP. The genotypes harvested at 16WAP had DMC which ranged from 12.5% to 28.0% with mean of 24.8%. At this stage, most genotypes could be harvested for human consumption and for other value additions.

At 20WAP, the mean DMC was 25.6%. This ranged from 12.5 to 28.0%. This indicated that DMC accumulation of the marketable roots have reached it ceiling for most genotypes. Those genotypes with high dry matter content of 27 to 28.0% could be harvested for human consumption, as article for commerce or for other value additions. Idowu and Kupoluyi (2008) reported that sweetpotato storage roots with dry matter content of 28 to 34% could be used to process sweetpotato products such as: gari, bread, cake, biscuits, cookies, chips, flour, chin chin, doughnut, puff puff, meatpie,starch, juice, kunnu, microbiological agar ethanol and bio-fuel.

CONCLUSION

Sweetpotato genotypes vary remarkably in their marketable root bulking and maturity dates this indicates that earlier harvests render immature unmarketable size, resulting in the penalty of low yield. This is also evidenced by high percentage of small roots. Harvesting at that stage render storage roots immature and unmarketable. It is evident that bulking was interrupted at 8 WAP in all test clones and it was observed that some of the genotypes required more than 16 WAP to reach maturity. Nevertheless, almost all clones showed good marketable tuber weight and number when harvested at 16 WAP. It is therefore recommended that harvesting should be at 16 WAP. Assigning genotypes to a given harvest date is of paramount importance for: areas of short growing seasons as a result of short rainfall, areas of high disease infestation, areas with high market demand, for industrial uses and depends on type of utility of the storage roots

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SOIL FERTILITY MANAGEMENT OF FARM HOUSEHOLDS AND FOOD SECURITY NEXUS: EMPIRICAL EVIDENCE FROM ABIA STATE, NIGERIA.

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ABSTRACT

The study examined soil fertility management of farm households and food security nexus in Abia State, Nigeria. Through a carefully structured questionnaire, primary data were collected from 180 arable crop farm households. Data collected were analysed using descriptive statistics such as frequency, percentage, food security index and inferential statistics such as binary logistic regression, multinomial logit model and principal factor analysis. The results of the study showed that majority (53.9%) of the farm households are food insecured while 46.1% are food secured. Majority of the food insecured farmers engaged the use of organic manuring while the highest proportion of the food secured farmers engaged the use of inorganic manuring. The result of the binary logistic regression was highly significant at 1% (prob> chi^2 = 0.000), Pseudo R^2 = 0.8219 and showed that age, sex, education, household size, farm size, credit access and farm income significantly influenced poverty status of the farmers. The result of multinomial logistic regression also showed good fit with prob> chi^2 = 0.000 and Pseudo R^2 = 0.7410. Age, sex, education, household size, farm size, extension visits, credit access and farm income significantly influenced farmers' choice of soil fertility management options. Through data reduction, the challenges of farmers in soil fertility management practices are instructional, financial and social factors. Based on the findings, this study among others recommended increase knowledge and technical know-how of farmers in effective use of fertilizers for improved yield and productivity, increased provision of credit facilities to farm households to increase their purchasing power of relevant farm inputs such as fertilizers to boost agricultural production and consequently reduce food insecurity.

Keywords: Soil fertility, organic, inorganic manure, food security, Abia State

INTRODUCTION

One of the fundamental components of socioeconomic development of any society is adequate food production and security. Food security is a condition where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Eme, *et al*, 2014). Food security exists at five different levels which include: individual, household, national, region and global (Perez-Escamilla, *et al*, 2017). To a household for instance, Ugo (2021) described food security as access by all members of the household at all times to enough food for an active, healthy life. The issue of food security has been on the front burner in Africa continent due to her low capacity to cope with food requirement of the rising population.

Africa is regarded as the most food-insecure continent in the world, and for decades hunger has always been a serious problem in the continent (Bwalya, 2013). Food insecurity and poor nutrition have been found to be prevalent in Sub-saharan Africa, Nigeria as poverty headquarters inclusive. Dwindling trend in food production across Africa is not unconnected with soil degradation and depletion in soil fertility. About 2.6 billion people are estimated to depend directly on agriculture for their livelihood and 52% of the land used for agriculture is either moderately or severely affected by soil degradation (Gabathuler, *et al*, 2009). One of the reasons for recurrent failure of food self-sufficiency plans is underestimation of the importance of soil fertility status and lack of clear-cut intervention plan to address soil nutrients depletion problems. Soil nutrients depletion has become serious threats to agricultural productivity in sub-Saharan Africa. It is getting worst in Nigeria and southeast zone in particular due to increased pressure on available farmland. Most arable lands have been affected by degradation thereby reducing agricultural productivity, which in turn results in poor economic growth and food insecurity in sub-sahara Afrcian countries (Bekele, 2003). Soil degradation will remain an important global concern because of its adverse impacts on agricultural production and food security. Inappropriate soil management, particularly in areas with high population densities and fragile ecosystems, further increases loss of productivity of resource poor farmers. This in turn worsens food insecurity status and livelihood of farm households in developing countries (FAO, 2001).

There is a strong tie between soil fertility management and food security through improved food production. For instance, Jorhan (2022) stated that to achieve and maintain food security, strong policies and decision making are required at local and global levels to increase food production through sustainable soil fertility management. Effective soil fertility management, no doubt will play significant role in achieving Sustainability Development Goal (SDG) 2 which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. Gebrehiwot (2022) pointed out that soil fertility management enhances food security of the world population. Soil fertility can be maintained or increased through several soil management practices. FAO (2021) noted that farmers can improve soil fertility and soil health by optimizing soil nutrient management in terms of maximizing net returns, minimizing the soil nutrients depletion, and minimizing nutrient losses or negative impacts on the environment.

Farmers have options of boosting or managing the fertility of the soil for improved productivity through the use of organic manures, inorganic fertilizers or the combinations of both (Ullah, *et al*, 2008). The productivity of some arable lands had declined by 50% as a result of soil fertility depletion, erosion and desertification (Mitiku, Herweg and Stillhardt, 2006). Hence, there is need to emphasize the importance of soil fertility management as a means of improving agricultural productivity to solve food insecurity problems in Africa (FAOSTAT, 2016). In this regards, this study examined soil fertility management of farm households and food security nexus in Nigeria with empirical evidence from Abia State. The study specifically, examined food security status of the farmers, soil fertility management and food security nexus, determinants of food security status of farmers, factors influencing soil fertility management practices and challenges of farmers in soil fertility management practices.

METHODOLOGY

Area of Study

The study area was Abia State in southeast geopolitical zone, Nigeria. The state lies between longitudes 7^{O} 10^{1} and 8^{O} East of the Greenwich meridian and latitudes 4^{O} 40^{1} and 6^{0} 14^{1} North of the equator. Abia State is made up of 17 Local Government Areas (LGAs) broadly divided into three agricultural zones namely: Aba, Ohafia and Umuahia agricultural zones. The population of the state is 3,256,642 people and land area of about 5,243.775sq.km (National Bureau of Statistics, 2012). Abia State is an agrarian state making it suitable for housing notable agricultural institutions such as National Root Crops Research Institute (NRCRI) and Michael Okpara University of Agriculture. Agricultural activities ranging from production, processing to marketing constitute means of livelihood of the people, providing employment and income for more than 65% of the population.

Sampling Techniques

This study adopted multi-stage sampling technique for selecting 180 smallholder arable crop farmers across the state. The first stage involved purposive selection of the three agricultural zones (Aba, Ohafia and Umuahia) due to wide spread cultivation of arable food crops across the entire state. At the second stage, two LGAs were randomly sampled from each of the three agricultural zones, making a total of six LGAs for the study. The third stage of the sampling equally involved random selection of two communities from each of the six LGAs making 12 communities for the study. With the help of agricultural extension agents at the local government and key informants in the selected communities, the lists (sampling frame) of the smallholder arable crops farmers were compiled from which the sample was drawn. Hence, the fourth stage of the sampling involved random selection of 15 smallholder arable crop farmers from each of the 12 selected communities making a total of 180 farmers that constituted the sample (respondents) for the study.

Data Collection and Analysis

Data for this study were obtained from primary source through the use of structured questionnaire between April and May, 2021 by the researchers and research assistants through personal contacts with the farmers. The questionnaire was structured to collect data on socio-economic characteristics of the farmers, food security status, soil fertility management practices and challenges facing the farmers in soil fertility management. Data collected were analysed using descriptive statistics such as frequency, percentage, food security index and inferential statistics such as binary logistic regression, multinomial logit model and principal factor analysis.

Estimation procedure

Food Security Index

Food security index in this study was estimated using expenditure approach as used by Zubairu and Maurice (2014) and Haddabi, Ndehfru and Aliyu (2019) to categorize the farm households into food secured and food insecured. The is given as;

$$Fi = \frac{per\ capita\ food\ expendirure\ for\ the\ ith\ household.}{2/3\text{ mean per capita food expenditure for all households}} \ldots (1)$$

Where:

Fi = Food Security Status.

When Fi ≥ 1, the ith household is food secured.

When Fi ≤ 1, the ith household is food insecured.

Therefore, from the above estimation, food secured households are those whose per capita monthly food expenditure fell above or is equal to two-third (2/3) of the mean per capita food expenditure while food insecured households are those whose per capita food expenditure fell below two-third (2/3) of the mean monthly per capita food expenditure.

Binary Logistic Regression

The binary logistic analysis was used to estimate the determinants of food security status of the arable crop farmers' households. The food security status (Y) of the farmers' households was already obtained as 1 if a farm household is food secured and 0 if the farm household is food insecured. The logistic model is specified explicitly as:

$$Fi = b0 + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6 + b7X7 + \cdots ..\mathrm{e} \quad (2)$$

Where:

*F*i = Food Security Status (1 = if food secure, 0 = if food insecure).

X_1 = Age of farmers (in years)

X_2 = Sex (1 = if male, 0 = if female)

X_3 = Educational level (number of years spent in school)

X_4 = Farming experience (number of years)

X_5 = Household size (number of persons)

X_6 = Membership of associations (1 = 1f a member, 0 = if otherwise)

X_7 = Farm size (in hectare)

X_8 = Extension contact (number of visits)

X_9 = Access to credit (in naira)

X_{10} = Labour (in mandays)

X_{11} = Farm income (in naira)

$b_1 – b_{11}$ = Coefficient of independent variables

$X_1–X_{11}$ = Determinants of farmers security status

e = Stochastic error term.

Multinomial Logit Model

Multinomial logit (MNL) regression model was used in this study to express the probability of an arable crop farmer using a particular soil fertility management option being organic manure, inorganic fertilizers or engaging both organic and inorganic. The general form of the multinomial Logit model is:

$$\Pr(yi = j) = \frac{exp(Xi\beta j)}{1 += \sum_{j=1}^{j} exp(Xi\beta j)} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

$$\Pr(yi = 0) = \frac{1}{1 += \sum_{j=1}^{j} exp(Xi\beta j)} \ldots \ldots . \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . (4)$$

Where:

For the ith farmer, *yi* is the observed outcome and *Xi* is a vector of explanatory variables. βj is the unknown parameters. This model for this study was summarized as follows:

$$P\,ij = \frac{exp(YjXi)}{1 + \sum_{j=1}^{3} exp(YjXi)\ \ for\ j = 1, 2, 3} . (5)$$

Pij is the probability of being in each of the groups 1, 2 and 3.

$$P\,io = \frac{1}{1 + \sum_{j=1}^{3} exp(YjXi)\ \ for\ j = 0} . (6)$$

Pi_o is the probability of being in the reference group or group 0. In practice, when estimating Multinomial Logit model, the coefficients of the reference group are normalized to zero (Maddala 1990 and Greene 1993). Hence, for the 3 choices only (3 - 1) sets of parameters can be identified and estimated. The natural logarithms of the odd ratio of equations (1) and (2) give the estimating equation (Greene 1993) as:

$$\ln = \left(\frac{Pij}{Pi0}\right) Xi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

This denotes the relative probability of each of the groups 1, 2 and 3 to be reference group. The estimated coefficients for each soil fertility management choice therefore reflect the effects of Xi's on the likelihood of the farmers using that alternative relatives to the reference group. The coefficients of the reference group may be recovered by using the formula:

$$Y_3 = -(Y_1 + Y_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

In this study however, group 1 are farmers using organic manuring, group 2 are farmers using inorganic fertilizers while group 3 are farmers engaging the use of both organic and inorganic fertilizers in managing soil fertility. For each explanatory variable, the negative of the sum of its parameters for groups 1 and 2 is the parameter for the reference group. The reference group (base outcome) in this study is group 3 (engaging both organic and inorganic fertilizers). The explicit form of the functions is specified as follows:

$$Pij = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta7X7 + \beta8X8 \ldots + n \ldots\ldots\ldots (9)$$

P_{ij} = (probability of using organic manure, inorganic fertilizers or combination of both)

X_1 = Age of farmers (in years)

X_2 = Sex (1 = if male, 0 = if female)

X_3 = Educational level (number of years spent in school)

X_4 = Farming experience (number of years)

X_5 = Household size (number of persons)

X_6 = Labour (in mandays)

X_7 = Farm size (in hectare)

X_8 = Extension contact (number of visits)

X_9 = Access to credit (in naira)

X_{10} = Membership of associations (1 = 1f a member, 0 = if otherwise)

X_{11} = Farm income (in naira)

X_{12} = Food Security Status (1 if food secure, 0 if food insecure)

e = Stochastic error term.

Factor Analysis

Principal component factor analysis model was employed for analysing the challenges of farmers in soil fertility management in the area:

$$Y_1 = a_{11}X_1 + a_{12}X_2 + * * * + a_{1n}X_n$$
$$Y_2 = a_{21}X_1 + a_{22}X_2 + * * * + a_{2n}X_n$$
$$Y_3 = a_{31}X_1 + a_{32}X_2 + * * * + a_{3n}X_n$$
$$* = \qquad *$$
$$* = \qquad *$$
$$Y_n = a_{n1}X_1 + a_{n2}X_2 + * * * + a_{nn}X_n$$

Where:

Y_1, Y_2 …Y_n = observed variables/challenges to arable crop farmers in soil fertility management.

$a_1 - a_n$ = factor loadings or correlation coefficients.

X_1, X_2 … X_n = unobserved underlying factors facing arable crop farmers in soil fertility management.

RESULTS AND DISCUSSION

Food Security Status of the Farmers

The value of total expenditure on food by the arable crop farm households per month (THEFPM) was ₦6,458,299.20; the mean per capita household expenditure (MPCHE) was ₦35,879.44 while two-third (2/3) of mean per capita household expenditure (2/3 MPCHE) was = ₦23,919.63. Therefore, based on the benchmark of ₦23,919.63 (2/3 MPCHE), 46.1% of the farm households are food secured while majority of 53.9% of the farm households are food insecured. The result clearly depicts general food insecurity among farm households in the state. Osuji, *et al*, (2017) in a study found that majority of farm households in Imo State are food insecure since the proportion of food insecured households is greater than that of food secured farm households. Similarly, Opaluwa, *et al*, (2019) in a study found that 46.7 percent and 53.3 percent of farm households in Kogi State were food secured and in secured respectively. The result in Table 2 established the nexus between farm households' food security status and soil fertility management. From the result, only 8.3% of the food secured farm households are sole organic manure users while 36.1% of food insecured farm households are organic manure users. On the other hand, 25.6% of the food secured farm households are inorganic manure users while only 7.8% of food insecured farm households use inorganic manure. About 12% of the food secured households combine both organic and inorganic manure while 10.0% of the food insecured farm households practice the combination of organic and inorganic fertilizers for soil fertility management. The results clearly showed that the highest proportion of the food insecured farm households engaged in the use of organic manuring while the highest proportion of the food secured farm households engaged the use of inorganic manuring (fertilizers) for soil fertility management. The rising cost of inorganic fertilizer in Nigerian markets will naturally place the commodity out of the reach of the resource poor farmers and therefore may be responsible for the shift of food insecured farmers towards organic manure use. Alabi, Adams and Abu (2016) affirmed that inorganic fertilizers are becoming more expensive in Nigerian markets, thereby forcing resource poor farmers to consider organic manure use. Olayide, *et al* (2010) noted that inorganic fertilizers is not affordable for an average farmer in Nigeria and that may be responsible low use of inorganic fertilizers by the farmers. Obisesan, Akinlade and Fajimi (2013) in a study found that access to credit and fertilizer price were significant factors influencing the use of inorganic fertilizer among farmers.

Determinants of Food Security Status of the Farmers

The result of the binary logistic regression analysis in Table 3 showed that the explanatory power of the specified variables as indicated by the pseudo R^2 value of 0.8214 was high and good. This indicates that the estimated independent variables in the logistic regression are responsible for about 82% variation in arable crop farmers' food security status. The overall goodness of fit of the result as reflected by Prob>Chi^2 (0.000) was also good. In terms of consistency with *a priori* expectations on the relationship between the dependent variable (poverty status) and the explanatory variables, the model had behaved well. Out of the eleven explanatory variables specified in the model, seven statistically and significantly influenced poverty status of the farmers. The significant variables include: age, sex, education, household size, farm size, credit access and farm income.

Age of the farmers was significant and negatively related with poverty status at 5%. This indicates that as age of the farmers increase, their food security status reduces. In other words, aged or older farmers are more likely to be food insecured considering their weakness and possible decline in economic activities which may affect their food security status. Haddabi, et al (2019) noted that older household heads may not have the ability to obtain off-farm jobs and income to improved their food security like the younger household heads. Oluwatayo (2012) in a study identified age of households' heads as a major factor influencing food security status of households.

Sex of the farmers was highly significant and positively signed with poverty status at 1% indicating that male farmers tend to be more food secured. Hence, male farmers are more mobile and able to seek other means of likelihood to achieve food security than women. Ndobo (2013) found that the probability of food security decreases if household is headed by a female.

Table 1: Food Security Status of Smallholder Arable Crop Farmers in the Abia State

Indicators	Food Security Indexes	Frequency	Percentage (%)
THEFPM	= ₦6,458,299.20		
MPCHE	= ₦35,879.44		
2/3 MPCHE	= ₦23,919.63		
Food secure		83	46.1
Food insecure		97	53.9
TOTAL		180	100.0

Note: THEFPM = Total Households Expenditure on Food per Month; MPCHE = Mean Per Capita Household Expenditure; Source: Field Survey, 2021

Table 2: Soil Fertility Management and Food Security Nexus of Smallholder Arable Crop Farmers in Abia State

Indicators	Food Security Indexes	Frequency	Percentage (%)
THEFPM	= ₦6,458,299.20		
MPCHE	= ₦35,879.44		
2/3 MPCHE	= ₦23,919.63		
Organic manure users			
> 2/3 MPCHE (Food secure)		15	8.3
< 2/3 MPCHE (Food insecure)		65	36.1
Inorganic manure users			
> 2/3 MPCHE (Food secure)		46	25.6
< 2/3 MPCHE (Food insecure)		14	7.8
Users of both organic & inorganic			
> 2/3 MPCHE (Food secure)		22	12.2
< 2/3 MPCHE (Food insecure)		18	10.0
TOTAL		180	100

Note: THEFPM = Total Households Expenditure on Food per Month;
MPCHE = Mean per Capita Household Expenditure; Source: Field Survey, 2021

Table 3: Binary Logistic Regression Estimates of Determinants of Food Security Status of Arable Crop Farmers in Abia State

Regressors	Coefficients		*Z*-ratios
CONSTANT	0.8213153	(0.0720643)	11.39***
Age of farmers (X_1)	-0.0676606	(0.0292415)	-2.31**
Sex of farmers (X_2)	0.0359089	(0.0099968)	3.59***
Years of education (X_3)	0.1506238	(0.0343821)	4.38***
Farming experience (X_4)	0.002915 (0.0234885)		0.12
Household size (X_5)	-0.0451466	(0.0239725)	-1.88*
Cooperative membership (X_6)	0.0060749	(0.1708392)	0.04
Farm size (X_7)	0.0334686	(0.0087769)	3.81***
Extension visits(X_8)	0.052217 (0.1102829)		0.47
Credit access (X_9)	1.361908	(0.2667186)	5.10***
Labour (mandays) (X_{10})	-0.2683162	(0.4857895)	-0.55
Farm income (X_{11})	1.730436	(0.4623602)	3.74***
LR chi^2	233.31		
Pseudo R^2	0.8219		
Prob> chi^2	0.000		
Observations	180		

Note: Figures in parentheses are standard errors.
*** denotes sig. at 1%; ** denote sig at 5% while * denotes sig. at 10%
Source: Field Survey, 2021.

Year of formal education was positive and significantly related with food security at 1%. This suggests that increase in education enhances the likelihood of farm households being food secured. This is expected, as educated farmers are likely to be more productive in farming and other economic activities that will boost their food security status than illiterate ones. Opaluwa, Opeyemi, Ajibade and Jonah (2019) in a study identified education as a strong factor improving food security of farming households. The coefficient of household size was also significant but negatively signed with food security status at 10%. This indicates that as member of household increase, the probability of food security decreases as the households now have more members to feed and cater for. Abu and Soom (2016) in a study equally established negative relationship between household size and food security.

The coefficient of farm size was highly significant at 1% and positively signed with food security. This implies that the larger the household farm size, the higher the probability of the household being food secured. Large farm sizes could translate to higher farm outputs and productivity that will enhance food security of the household. The findings of Henri-Ukoha, *et al.,* (2013) and Osuji, *et al,* (2017) showed that significant and positive relationship exist between farm size and food security of farming households. Access to credit was highly significant at 1% and positively related to food security status of the farmers. This indicates that as farmers have more access to credit, their probability of being food secured equally increases. This is in line with *a priori* expectation as farmers' access to credit will increase financial resources at their disposal to purchase needed inputs such as improved seeds, fertilizers, labour and agrochemical for improved output. This corroborated the findings of Pappoe (2011) and Osuji, *et al,* (2017) that availability of farm credit is crucial factor that enhance food security of farmers' households. The coefficient of farm income was highly significant a 1% and positively signed with poverty status. As farmers' incomes increase, their purchasing power naturally step up and there is likelihood to invest in more income generating activities that will increase their access to food in both quantity and quality. Babatunde, *et al* (2007) reported that farm households' income is the sum of earnings from both off-farm and on farm sources. Abu and Soom (2016) found that income of farm households heads had a positive impact on their households' food security.

Factors Influencing the Choice of Soil Fertility Management Practices of the Farmers

The determinants of choice of soil fertility management in this study were hypothesized to depend on a number of socio-economic factors. Multinomial logit (MNL) model was used to estimate socioeconomic factors that influenced farmers' choice of soil fertility management option (sole organic manuring, sole inorganic manuring and engagement of both). This was estimated by normalizing one category, which is referred to as the "reference state," or the "base category." In this analysis, the base category is the group 3 that engaged both organic and inorganic manuring against which comparisons are made in each case.

The likelihood ratio statistics as indicated by Prob> chi^2 (χ^2) statistics is highly significant ($p<0.0000$) at 1%. The explanatory power of the factors as reflected by Pseudo R^2 was high 0.7410, indicating that the hypothesized variables in the model are responsible for about 74% variation in the farmers' choice of soil fertility management option. In terms of consistency with *a priori* expectations, the model had behaved well. Identified socioeconomic variables that significantly influenced farmers' choice of soil fertility management include: age, sex (gender), education, household size, farm size, extension visits, credit access, farm income and food security status.

Age of farmers was significant at 5% and positively related to the probability of using organic manuring but was negative and significantly related to inorganic fertilizer use. The result indicates that as farmers grow older, their tendencies to use organic manure increase while their likelihood to engage the use of inorganic fertilizers decreases. The coefficient of sex (gender) of farmers was not significant for organic manure use but significant and positively related to inorganic fertilizer use at 5%. This implies that male farmers are more disposed to the use of inorganic fertilizers than their female counterparts. Beshir, Emana, Kassa and Haji (2012) found that age, farm land size and gender significantly influence adoption of inorganic fertilizer. Years of formal education was highly significant at 1% and inversely (negatively) related to organic manure use but positively and significantly related to inorganic fertilizer use at 1%. It is expected that educated farmers are likely to be more knowledgeable about the composition and application of inorganic fertilizers. Obisesan, Akinlade and Fajimi (2013) reported that farmers with higher level of education are more likely to prefer inorganic fertilizer to boost crop production.

Household size was significant at 5% but inversely related to organic manure use. It was highly significant (1%) and positively signed with inorganic fertilizer use for soil fertility management. The implication of this result is that, as household size increases, the tendencies to shift towards organic manure use decreases while the likelihood to use inorganic fertilizer increases. The coefficient of farm size was highly significantly at 1% and negatively related to organic manure use but positively and significantly related to inorganic fertilizer use at 1%. Application of organic manure for large expanse of land will definitely be labour intensive and hence can greatly be discouraged as farm size increases. Milkessa (2020) in a study found that farm size and membership to farmer groups influenced the use and intensity of adoption inorganic fertilizer use.

Extension visits was significantly at 5% and negatively signed with organic manure use but positively and significantly related to inorganic fertilizer use at 5%. This indicates that the more the number of extension visits to farmers, the less their likelihood to use organic manure and the more their tendencies to use inorganic fertilizers. Beshir, *et al*, (2012) found that extension and credit services enhance the adoption of inorganic fertilizer. The coefficients of access to credit and farm income were both highly significantly at 1% and negatively related to organic manure use but positive and significantly related to inorganic fertilizer use at 1%. Obisesan, Akinlade and Fajimi (2013) observed that credit access increases the level of inorganic fertilizer adoption and use. Farmers' increased credit and farm income will enhance their purchasing to buy required farm inputs such as inorganic fertilizers even at increased price. Similarly, Andre and Mulat (1996) in a study found that access to banking, extension services and education play significant role in inorganic fertilizer adoption.

Food security status of the farmers was highly significantly at 1% and inversely (negatively) influences organic manure use but positive and significantly related to inorganic fertilizer use at 1%. This suggests that food secure farmers are less likely to engage the use of organic manure but likely to tend towards the use of inorganic fertilizers due to their financial stability. Alabi, Adams and Abu (2016) affirmed that inorganic fertilizers are more expensive and out of the reach of average farmer. This explains the positive and significant relationship between farmers' food security status and the use of inorganic fertilizer.

Challenges Faced by Farmers in Soil Management Practices.

The table 5 below presents the varimax-rotated principal component factor analysis of challenges faced by farmers in soil fertility management in the study area. From the result presented in the Table, three (3) factors were extracted based on the responses of the respondents (crop farmers). The naming of each factor is based on the set of variables or characteristics the factor is composed of (Kessler, 2006). Hence, this study group the variables into three major components factors as; Factor 1 (instructional factor), factor 2 (financial factor), and factor 3 (social factor).
Under factor 1 (Instructional factors), the specific challenging variables of farmers in soil fertility management include; lack of access to extension visits (0.538), poor access to soil fertility management information (0.497), lack of knowledge about some fertility management practices (0.494), erosion challenges in the area causing leaching (0.422) and weak social network among farmers such as cooperatives (0.466). poor access to soil fertility management information (0.497) was among the challenges reported by Amusa and Enete and Okon (2015) to have loaded under the input factor as one of the specific challenging variables against farmers' practice of agronomic soil conservation. The challenges that fitted under factor 2 (Financial Factor) include, Non-availability of fertilizers in the market (0.438), High cost of inorganic fertilizers (0.514), Lack of finance/capital for purchasing fertilizers (-0.513), Inadequate farm labour in the area (0.416), porous nature of the soil in the area (0.407), poor access to credit sources (-0.407), Scarcity and competition on organic waste for livestock feeding (0.453).

Similarly, Ebe, Obike and Nnamani (2019) posited that major constraints hindering the farmers from practicing the soil management practices were inadequate finance, high cost of labour, cost of soil management practices, high cost/unavailability of some farm inputs and poor knowledge of some of the oil management practices. Supporting, the report of FAO (2017) shows that inadequate finance for acquiring farm inputs by farmers in developing countries further worsen the present hunger and poverty rise in the area. Enete (2003) reported that most financial institutions in developing countries do not usually lend to agriculture, not only because the farmers lack the basic collateral as a result of poverty, but also because the farming is considered very risky

The challenges that fall under factor 3 (social factors) are; tedious nature of soil fertility management practices/activities (0.421), unwillingness of some farmers to manage soil fertility (0.489), poor knowledge in organic fertilizer formation (0.498), low level of experience in fertilizer formation (0.532), poor access to and control over farm land (0.467), land tenure system practiced in the area (0.423), Poor attitudes of farmers towards fertility management (0.469). This is in line with the findings of World Bank (2018) showed that soil conservation efforts by most farmers in Nigeria is still very low resulting in the recorded high rate of soil degradation.

Table 4: Multinomial Logit (MNL) Regression Estimates of Determinants of the Choice of Soil Fertility Management Practices by Arable Crop Farmers in Abia State

	Organic Manuring			Inorganic Manuring		
Regressors	Coefficients		*Z*-ratios	Coefficients		*Z*-ratios
CONSTANT	-6.448059	(0.5723271)	-11.27***	1.108631	(0.0922676)	12.02***
Age of farmers (X_1)	0.0480909	(0.0231728)	2.08**	-0.0577226	(0.0246656)	-2.34**
Sex of farmers (X_2)	0.0373173	(0.8023891)	0.05	1.620107	(0.7149271)	2.27**
Years of education (X_3)	-0.0855255	(0.0248760)	-3.44***	0.3449075	(0.081032)	4.26***
Farming experience (X_4)	-0.0061664	(0.0385601)	-0.16	-0.0066218	(0.0304230)	-0.22
Household size (X_5)	-0.214566	(0.0956724)	-2.24**	0.0949620	(0.0246474)	3.85***
Labour (mandays) (X_6)	0.2950089	(0.3155776)	0.93	-0.2217512	(0.2068538)	-1.07
Farm size (X_7)	-0.2679274	(0.0611384)	-4.38***	0.3561431	(0.0773022)	4.60***
Extension visits(X_8)	-0.5295924	(0.2438209)	-2.17**	0.3322975	(0.1352458)	2.46**
Credit access (X_9)	-1.727612	(0.4988526)	-3.46***	2.084170	(0.6556445)	3.17***
Cooperative membership (X_{10})	0.5111507	(0.7177884)	0.71	0.0465219	(0.6551505)	0.07
Farm income (X_{11})	-1.313149	(0.3176135)	- 4.13***	2.865323	(0.7375423)	3.88***
Food security status (X_{12})	-0.0864321	(0.0264950)	-3.26***	0.0307434	(0.0065430)	4.70***
LR chi^2	210.69					
Prob> chi^2	0.000					
Pseudo R^2	0.7410					
Observations	180					

Note: Group (3) Choice of combining both organic and inorganic manuring is the Base Outcome
Figures in parentheses are standard errors; *** denotes sig. at 1%; ** denote sig at 5% while * denotes sig. at 10%
Source: Field Survey, 2021.

Table 5: Challenges of farmers in soil fertility management in Abia State

		Principal Components Factors		
SN	Challenges of farmers in soil fertility management:	Instructional Factor	Financial Factor	Social Factor
1	High level of illiteracy among farmers	0.381	-0.220	0.487
2	Lack of access to extension visits	0.538	-0.105	0.361
3	Poor access to soil fertility management information	0.497	-0.063	0.029
4	Lack of enough knowledge of fertility management	0.494	-0.261	-0.167
5	Tedious nature of soil fertility management practices	0.196	0.111	0.421
6	Non-availability of fertilizers in the market	0.215	0.438	0.229
7	High cost of inorganic fertilizers	0.212	0.514	0.233
8	Unwillingness of some farmers to manage soil fertility	0.355	0.227	0.489
9	Poor knowledge in organic fertilizer formation	0.137	0.365	0.498
10	Lack of finance/capital for purchasing fertilizers	0.189	-0.513	0.025
11	Low level of experience in fertilizer application	-0.225	0.093	0.532
12	Erosion challenges in the area causing leaching	0.422	-0.092	-0.096
13	Inadequate farm labour in the area	-0.154	0.416	-0.286
14	Inadequate farm land resulting in continuous cropping	0.299	-0.515	0.411
15	Poor access to and control over farm land	0.011	-0.230	0.467
16	Land tenure system practiced in the area	0.270	-0.276	0.423
17	Porous nature of the soil in the area	-0.288	0.407	0.111
18	Rough topography of farm lands in the area	0.257	-0.064	-0.344
19	Poor attitudes of farmers towards fertility management	-0.167	0.193	0.469
20	Increased pressure on farmlands for other uses	0.485	0.444	-0.084
21	Poor access to credit sources	0.309	-0.407	0.355
22	Offensive odour of organic fertilizers/manure	0.385	0.044	0.089
23	Aversion of risks about profitability of fertilizer inputs	0.262	-0.196	-0.086
24	Weak social network among farmers e.g cooperatives	0.466	0.177	-0.323
25	Competition on organic waste for livestock feeding	0.059	0.453	-0.232

Note: Factor loading of 0.40 was used; Variables with factor loadings of less than 0.40 were not used.
**Variables 14 and 20 were discarded for loading in more than one factor.
Source: Field Survey, 2021.

CONCLUSION

The study examined soil fertility management of farm households and food security nexus in Abia State. From the data collected and analysed, the study found that majority (53.9%) of the farm households are food insecured while 46.1% are food secured. Highest proportion of the food insecured farm households engaged the use of organic manuring while the highest proportion of the food secured farm households engaged the use of inorganic manuring (fertilizers) for soil fertility management. Age, sex (gender), education, household size, farm size, credit access and farm income significantly influenced poverty status of the farmers. Also, age, sex, education, household size, farm size, extension visits, credit access, farm income and food security status significantly influenced farmers' choice of soil fertility management. The challenges of farmers in soil management practices are categorized into three factors which are instructional, financial and social factors. Based on the findings, this study recommended that:

i. Government and its relevant agencies at all levels should ensure increase knowledge and technical know-how of farmers in effective adoption and use of fertilizers for improved yield and productivity of crop farmers to boost food security status of farming households in the state and country in general.

ii. There should be increased provision of credit facilities to farm households in order to increase their purchasing power of relevant farm inputs such as fertilizers and agrochemical to boost agricultural production and consequently reduce food insecurity challenge.

iii. Government should also help farmers in mobilizing savings and make crucial inputs such as fertilizer readily available to the farmers at subsidized price to serve as incentive in improved food production that will guarantee food self-sufficiency and security.

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INFLUENCE OF PLANT EXTRACTS AND STORAGE METHODS ON THE PHYSIOLOGICAL QUALITY OF POTATO (*Solamun tuberosum)* TUBERS IN YOLA, ADAMAWA STATE-NIGERIA

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ABSTRACT

Nigeria is experiencing huge postharvest losses of potatoes that require urgent remedy to improve food security and standard of living. In view of the forgoing, this study was designed to determine the impact of plant extracts and storage methods on the preservation of physiological quality of potato tubers. The study consisted of two factors; plant extracts and storage methods that were laid out in a Split Plot Design (SPD). Plant extract was assigned to the main plots with storage methods allotted to the sub-plot and then replicated three (3) times. Data were generated on percentage weight loss, change in tuber length, girth, deterioration and sprouting. These parameters were subjected to Analysis of Variance (ANOVA), and the results obtained exhibited a highly significant ($P < 0.01$) effect of both factors on percentage weight loss, deterioration and sprouting of potato tuber. Neem leave and ginger powder together with storage in either perforated plastic bag or fibre board carton with saw dust is therefore recommended as an effective technology for preserving potato tubers.

Key words: Deterioration; Girth; Percentage; Sprouting; Tuber length

INTRODUCTION

Potato (*Solamun tuberosum)* is one of the most popular staple food in the world and considered as the king of vegetables (Ayalew & Hirpa, 2014) because they combine both the wholesomeness of cereals, delicacy and characteristic chemical constituents of vegetables. Nutritional deficiency is not common in countries that depend on potatoes as their stable food (Gumul *et al*., 2011). It is also an excellent source of starch, high percentage essential amino acid [lysine, leucine, phenyloalanine, threonine and valine], minerals [K, Mg, Fe, Cu, J and P] and vitamins of group B, folic acid, fat-soluble vitamin [E, K, C and carotenoid a precursor of vitamin A] (Gumul *et al*., 2016). In addition, it contains phytonutrients or antioxidants that help to inhibit oxidative reaction that lead to formation of free radicals or reactive oxygen species which cause degenerative reactions and chronic diseases. Potato is also considered as the third main source of dietary phenols after of apple and orange (Brar *et al*., 2017).

Another important nutritional constituent found in potato is dietary fibre which is approximately 2.5% on fresh mass basis which is essential in digestion by activating peristalsis; provide culture for beneficial intestinal microbes and influence hypoglicaemic and hypocholesterolaemic processes (Gumul *et al*., 2011). The fibre present in potato is also helpful in lowering cholesterol and improves functioning of insulin in the body, which also aids in lowering blood pressure (Aliyu, 2016).

Potatoes are high in carbohydrates and thus maintain good level of glucose in the blood which prevent brain fatigue and keep it active and alert. Furthermore, it contains carotenoids (lutein, zeaxanthin etc.) which are beneficial for the functioning of heart and other internal organs (Aliyu, 2016).

In Nigeria, potatoes are used for the production of various local dishes, flour, composite flour and starch (Bemba & Sadana, 2013) and it is estimated that potatoes provide about 15.1% and 8.0% of the total daily diet caloric and protein requirement respectively of average Nigerian (Olsen & Miller, undated; Toiessa, 2018).

Despite the huge nutritional benefits of potatoes to humans, about 40% of potatoes were lost during postharvest phase of its production due to poor handling and lack of modern storage facilities such as cold storage (Paul & Ezekiel, 2013). In addition, chemical based sprout suppressants storage methods have serious consequences on the environment (Paul & Ezekiel, 2006; Kulen *et al*., 2011; Paul *et al*., 2014) and most storage methods use by the farmers pay little attention to haleness and environment sustainability (Paul *et al*. 2002; Voss *et al*. undated; Paul & Ezekiel, 2013) thus there is the need to find a more environmentally friendly approach to the potato postharvest handling in the country.
The present practice of employing chemical based inhibitors, pesticides and poor storage methods that are inimical to both human health and the environment in addition to the physiological deterioration that occur during potato preservation which also have a detrimental influence on its quality attributes and consumer preference. These problems called for urgent effort to find a better postharvest management practice that would assist in extending potato shelf-life that would grant sufficient time for marketing and consumption.

Thus, there is he need to find a healthier and environmentally friendly plant based sprout inhibitor and a storage method. Therefore, this work was aimed at determining the effect of plant extracts and storage methods on the physiological quality parameters of potato tubers and also to ascertain the interaction that occurred between these factors on the physiological quality of potato tubers during storage.

MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm and the Laboratory of the Department of Crop Production and Horticulture, Modibbo Adama University, Yola. Yola is located between latitudes 9°14' and 9°19' N, and longitude 12°20' and 12°30' E. The area lies at an altitude of 158.5m above sea level, experiencing a mean maximum temperature of 40 °C in April and a minimum of 18 °C between December and January while the average annual rainfall is between 700 to 1050 mm (Adebayo,1999);as cited in Ahmed, 2016; Zemba *et al*., 2020).

The plant extracts powder were derived from Neem leaves (*Azadirachta indica* A. Juss) and Ginger (*Zingiber officinale* Roscoe) that were dried under shed, then grounded to powder using pestle and mortar. The powder was applied at the rate of 10 gm per twenty pieces of potato tubers before storage. The experiment comprises of two factors namely;

1. Plant extracts (neem leave powder, Ginger powder and untreated samples as control).

2. Storage methods (traditional basket made of bambo, underground pit, jute bag, perforated polypropylene bag, corrugated fibreboard carton containing saw dust and on the floor storage which serve as control.

These factors were factorial combined to give a 3 x 6 experiment which is laid out in a Split Plot Design (SPD), consisting of 18 treatments. Plant extracts was assigned to the main plot while the storage methods was allocated to sub-plot, then replicated three (3) times and data on physiological quality attributes were collected every two weeks until the end of the storage period (8 weeks).
The physiological quality parameters are:

1. Percentage physiological weight loss: Measurements of weight are taken on five tubers using electronic scale fortnightly till the 8^{th} week of storage. The difference between original and final weights were calculated then divided by the original weight and expressed in percentage. The Percentage weight loss was calculated using equation 1as described by Ahmed & Abubakar (2016); Abubakar *et al*. (2019).

$$Percentage\ physiological\ Weight\ loss = \frac{original\ weight\ of\ tuber - final\ weight\ of\ tuber\ \times 100}{original\ weight} \quad .(1)$$

2. Percentage change in tuber length: tuber length was determined using venier calliper by measuring the distance between the stem and apical ends of the tuber. The lengths of five sampled tubers were taken and their average obtained. The percentage change in tuber length was calculated using equation 2 as expressed by Ahmed & Abubakar (2016); Ahmed *et al*. (2019) with little modification by replacing diameter with length in the formula, as follows:

$$Percentage\ Change\ in\ tuber\ length = \frac{original\ length\ of\ tuber - final\ length\ of\ tuber\ \times 100}{original\ length\ of\ tuber} \quad (2)$$

3. Percentage change in tuber girth: tuber girth was determined using venier calliper by measuring the midpoint between stem and apical ends. The girths of five sampled tubers were obtained and their average calculated. The percentage change in tuber girth was calculated using equation 3 as reported by Ahmed & Abubakar (2016); Ahmed *et al*. (2019) as follows:

$$Percentage\ Change\ in\ tuber\ girth = \frac{original\ girth\ of\ tuber - final\ girth\ of\ tuber\ \times 100}{original\ girth\ of\ tuber} \ldots(3)$$

4. Percentage Deterioration: rotting tubers were identified and sorted out at every two weeks of sampling period and recorded. The figure obtained is converted into percentage using equation 4 as suggested by Ahmed and Abubakar (2016); Ahmed *et al*. (2019); Abubakar *et al*. (2019).

$$Percentage\ Deterioration = \frac{total\ number\ of\ tubers - number\ of\ remaining\ tubers \times 100}{total\ number\ of\ tubers} \quad (4)$$

5. Percentage sprouting: this was done by physically counting the number of tuber that sprouted during storage. The number is then subtracted from the total to get the unsprouted tubers and multiple by100 as expressed in equation 5 (Aliyu 2016; Abubakar *et al*. 2019).

$$PercentageSprouting = \frac{total\ number\ of\ tubers - number\ of\ unsprouted\ tubers\ \times 100}{total\ number\ tubers} \ldots\ldots\ldots.(5)$$

Data Analysis

All the data collected were analysed statistically using the Generalised Linear Models (GLM) procedure of Statistical Analysis System (SAS version 9.2 2009) and means showing significant difference were separated using Duncan's Multiple Range Test (DMRT) at 0.5% level of probability.

RESULTS AND DISCUSSION

Percentage Weight Loss

The percentage weight loss of Potatoes at different sampling period as affected by plant extracts and storage methods is presented in Table 1. There was highly significant difference ($P \leq 0.01$) of plant extracts on the percentage weight loss of potatoes at 2nd, 6th and 8th Weeks After Storage (WAS). Neem powder treatment recorded the lowest weight loss of 10.37%, 22.59%, 34.18% and 47.77% throughout the storage period then followed by ginger powder treatment whereas the highest weight loss was recorded on control sample during the storage. Significant difference ($P \leq 0.05$) impact of plant extracts also occurred among the treatments at 4th WAS. With to regard to storage methods, it had no significant difference ($P > 0.05$) on percentage weight loss of potatoes throughout the sampling periods. Similarly, no significant ($P > 0.05$) interaction was recorded among the treatments at all the sampling periods.

The highly significant impact noted on percentage weight at 2nd , 6th and 8th WAS can be attributed to the effect of plant extract in lowering the rate of water vapour loss by blocking the stomata opening of the periderm which is the major source of weight loss in potato especially in the tropical areas like Yola. Water vapour loss due to evaporative loss of cellular water through the stomata caused by vapour pressure difference between the tuber interior and outside environment caused weight loss. This finding is in agreement with Ozturk (2016); Pandey *et al.* (2017) who reported that postharvest application of some plant extract play a major part in checking water loss of potato tubers which affect weight loss. Similar result was also reported by Paul *et al*. (2002); Ray & Ravi (2005); Paul & Ezekiel (2013); Aliyu, (2016) who reported weight loss due to transpiratory and respiratory process led to overall losses. In this vein, Wilcox (2006); Dandago & Gungula (2011); Khanal & Uprety (2014); Ezeocha & Ironkwe (2017) also reported that water loss is directly proportional to wilting and weight loss which also lead to undesirable physiological changes in some roots and tubers.

Percentage Change in Tuber Length

There was no significant ($P > 0.05$) influence of plant extracts on potato tuber length at all the sampling periods (Table 2) nonetheless; control treatment revealed the highest percentage change in tuber length while lowest values were observed on tubers treated with neem leave powder. In the case of storage methods however, there was highly significant ($P \leq 0.01$) influence at 6th and 8th WAS. Throughout the storage periods, least percentage change in tuber length was recorded on both basket (5.37, 4.84, 4.30 and 3.44%) and pit (5.36, 4.90, 4.48 and 3.91%) storage whilst floor storage reported the highest percentage change in length (5.76, 5.42, 4.97. and 4.51%). There was however, no significant ($P > 0.05$) interaction noted throughout the storage periods as shown in Table 2.

The highly significant influence that storage methods had on tuber length at 6th and 8th WAS could be due to high transpiration and respiration caused by the exposure of the untreated sample to the elements of weather like high temperature, low relative humidity and fast moving air. This implies that floor storage in tropical condition especially where the temperature is high as obtainable in the study area is not recommendable. The results of this study is in tandem with Aliyu (2016);

Hassan *et al*. (2016); Ozturk (2016) who demonstrated that storage condition affect the percentage change in tuber length during storage.

Percentage Change in Tuber Girth

The Percentage change in potato tuber girth was not significantly ($P > 0.05$) affected by plant extracts during the 8 weeks of storage as presented in Table 3. On the other hand, percentage change in tuber girth had a highly significant ($P \leq 0.01$) effect on storage methods at 2^{nd} WAS while at 4^{th} WAS, percentage change in tuber girth was significantly ($P \leq 0.05$) affected. Storage in tradition basket posted the highest values of percentage change in girth at all the sampling periods. In contrast, there was no significant ($P > 0.05$) interaction between plant extracts and storage methods at all the sampling periods as shown in Table 3.

The highly significant effect of storage methods on tuber girth might be due to shrinkage of tubers caused by high transpiration and respiration. This outcome concurred with Kaur *et al*. (2009); Aliyu (2016) who found that floor storage methods exposes potato tubers to high temperature and low relative humidity which lead to increased respiration rate which subsequent caused weight loss and shrinkage in potato tubers.

Percentage Deterioration

There was highly significant ($P \leq 0.01$) effect of plant extracts on percentage deterioration at sampling period 2^{nd} and 4^{th} WAS (Table 4). In addition, control sample recorded the highest number of tuber rotten (3.0, 2.2, 1.9 and 2.1% respectively) during the 8 weeks of storage and the least percentage deterioration was displayed by potatoes subjected to both neem and ginger treatment as depicted in Table 4. In terms of storage methods, there was highly significant ($P \leq 0.01$) effect of storage methods on percentage deterioration of potato tuber again at 2^{nd} and 4^{th} WAS. Highest values were obtained on pit and lowest on perforated plastic bag storage at all the sampling periods. Conversely, interaction was not significant ($P > 0.05$) between the two factors under evaluation.

The highly significant effect of plant extracts and storage methods on percentage deterioration that manifested at both 2^{nd} and 4^{th} WAS might be caused by the effect of some substances present in the plant extract that had both anti-microbial and healing properties that speed up curing process of wounded potato tuber. Similarly, the perforated plastic bag is highly ventilated making the environment harsh for microbial survival whereas the warm and humid condition of pit storage favoured microbial development. The findings of this study is in conformity with Bdliya (2006); Aliyu (2016); Ezzat *et al.* (2016) who stated that, disease incidence was significantly lower following the treatment with neem leaf extract under ventilated storage structures regardless of tuber condition and exposure time to the extracts. They also revealed that botanical pesticides have found much usage in pest and disease management nowadays due to environment considerations of chemical pesticides.

Percentage Sprouting

There was a highly significant ($P \leq 0.01$) influence of plant extracts on potato tuber sprouting percentage at 4^{th} WAS only (Table 5). Despite that, neem treated tubers had the lowest percentage sprouting while sample not treated with plant extracts had highest percentage sprouting throughout the study period. In the same vein, storage methods had a highly significant ($P \leq 0.01$) influence on percentage sprouting at 4^{th} and 6^{th} WAS. At all the sampling period, pit storage posted the highest percentage sprouting than other storage methods which may be attributed to the moist and warm condition provided by this storage method which is favourable for sprouting. In case of interaction, plant extract sand storage methods had no significant (P > 0.05) interactive influence on percentage sprouting of potatoes (Table 5).

The highly significant influence of plant extracts on sprouting reported at 4th WAS might be the plant extracts used had some sprout suppression properties and this outcome is in consonant with Aliyu (2016); Teme *et al*. (2019) who showed that neem and ginger extract had some sprout suppressant effect on potato tuber sprouting during storage.

In the same vein, the highly significant influence storage methods on percentage sprouting at 4th and 6th WAS could be due to the high soil moisture, high relative humidity and temperature that provided favorable sprouting conditions by pit storage methods. The result of this work agrees with Ray & Ravi (2005); Victor (2009); Dandago & Gungula (2011); Aliyu (2016); Teme *et al*. (2019) who posited that pit storage method had high rate of sprouting due to high soil moisture and relative humidity.

CONCLUSIONS

This research has exhibited that plant extracts and storage conditions help to preserve most of the desirable physiological quality attributes of potato tubers during storage. The findings of this study further showed that treating potato tubers with neem or ginger had desirable effects on percentage weight loss, percentage deterioration and percentage sprouting whereas storing potatoes inside perforated plastic bag and carton with saw dust had favorable influence on percentage weight loss, tuber length, tuber girth, deterioration and sprouting during storage. Therefore, treating potato tubers with neem or ginger with either perforated plastic bag or carton containing saw dust should be adopted as an effective technology for preserving the physiological quality of potato tubers.

Table 1: Effect of plant extracts and storage methods on percentage weight loss of potato tubers

Storage Period	2WAS	4WAS	6WAS	8WAS
Treatment				
Plant Extract				
Neem	10.37^b	22.59^b	34.18^b	47.77^b
Ginger	12.96^b	30.37^a	38.51^b	50.00^b
Control	20.74^a	32.59^a	48.14^a	63.33^a
Pro. of F	0.001	0.054	0.001	0.001
S.E (±)	1.318	2.84	1.386	3.220
Storage Method				
Pit	18.51^a	31.11^a	45.18^a	60.00^a
Floor	15.55^a	26.66^a	41.48^a	54.07^a
Basket	14.70^a	26.66^a	40.00^a	51.11^a
Plastic Bag	12.59^a	25.92^a	40.00^a	53.33^a
Jute Bag	12.59^a	31.11^a	37.77^a	51.11^a
Carton	14.18	29.63	36.51	52.59
Prob. of F	0.207	0.89	0.21	0.17
S.E (±)	1.617	4.50	2.562	1.600
Interaction	NS	NS	NS	NS

Values with the same superscript in the same column are not significantly different SE= Standard error, Prob. of F= Probability of F, NS= Not significant

Table 2: Effect of plant extracts and storage methods on percentage change in tuber length of potato tubers

Treatment	Storage period 2 WAS	4 WAS	6 WAS	8 WAS
Plant extract				
Neem	5.50[a]	5.039[a]	4.655[a]	4.03[b]
Ginger	5.41[a]	5.044[a]	4.600[a]	3.944[b]
Control	5.50[a]	5.144[a]	4.677[a]	4.238[a]
S.E (±)	0.112	0.1307	0.940	0.135
Prob. of F	0.741	0.700	0.749	0.030
Storage Conditions				
Traditional basket	5.37[ab]	4.84[b]	4.30[c]	3.44[d]
Underground pit	5.36[ab]	4.90[b]	4.48[bc]	3.91[c]
Jute bags	5.56[ab]	5.22[ab]	4.75[ab]	4.10[bc]
Open floor inside room	5.76[a]	5.42[a]	4.97[a]	4.51[a]
Perforated plastic bag	5.46[ab]	5.07[ab]	4.64[b]	4.08[a]
Carton with saw dust	5.30[b]	4.98[ab]	4.70[ab]	4.38[ab]
S.E (±)	0.0951	0.1016	0.0773	0.0671
Prob. of F	0.445	0.59	0.001	0.001
Interaction	NS	NS	NS	NS

Values with the same superscript in the same column are not significantly different SE= Standard Error, Prob. of F= Probability of F, NS= Not significant.

Table 3: Effect of plant extracts and storage methods on percentage change in tuber girth of potato tubers

Treatment	2 WAS	Storage 4 WAS	Period 6 WAS	8 WAS
Plant Extract				
Neem	2.67[a]	2.294[a]	2.011[a]	1.572[a]
Ginger	2.60[a]	2.255[a]	1.667[a]	1.444[a]
Control	2.62[a]	2.272[a]	1.967[a]	1.622[a]
Prob. of F	0. 787	0.929	0.388	0.137
SE	0.642	0.0552	0.263	0.154
Storage Conditions				
Traditional basket	3.06[a]	2.57[a]	2.23[a]	1.51[a]
Underground pit	2.62[b]	2.22[b]	1.86[a]	1.388[b]
Jute bags	2.61[b]	2.30[b]	1.96[a]	1.63[a]
Open floor inside	2.64[b]	2.26[b]	1.94[a]	1.60[a]
Perforated plastic bags	2.36[b]	2.05[b]	2.37[a]	1.46[a]
Cartons and saw dust	2.50[b]	2.22[b]	1.93[a]	1.67 [a]
SE	0.090	0.054	0.378	0.123
Prob. of F	0.003	0.031	0.444	0.213
Interaction	NS	NS	NS	NS

Values with the same superscript in the same column are not significantly different SE= Standard error, Prob. of F= Probability of F, NS= Not significant

Table 4: Effect of plant extracts and storage methods on percentage deterioration of potato tubers

		Storage	Period	
Treatment	2 WAS	4 WAS	6 WAS	8 WAS
Plant extract				
Neem	1.0^{b}	1.3^{b}	1.9^{a}	1.4^{a}
Ginger	1.4^{b}	1.2^{b}	1.5^{a}	1.4^{a}
Control	3.0^{a}	2.2^{a}	1.9^{a}	2.1^{a}
Prob. of F	0.001	0.008	0.492	0.163
S.E (±)	0.29	0.213	0.29	0.25
Storage Conditions				
Traditional basket				
Underground pit	2.2^{a}	2.4^{a}	2.7^{a}	2.2^{a}
Jute bags				
Open floor inside room	2.1^{a}	1.8^{ab}	1.4^{ab}	1.3^{a}
Perforated plastic bag	1.4^{b}	1.4^{b}	1.3^{b}	1.3^{a}
Carton with saw dust	1.7^{b}	1.4^{b}	1.5^{a}	1.5^{a}
S.E (±)	0.36	0.36	0.30	0.43
Prob. of F	0.001	0.008	0.492	0.163
Interaction	NS	NS	NS	NS

Values with the same superscript in the same column are not significantly different SE= Standard error, Prob. of F= Probability of F, NS= Not significant

Table 5: Effect of plant extracts and storage methods on percentage sprouting of potato tubers

Storage Period	2WAS	4WAS	6WAS	8WAS
Treatment				
Plant Extract				
Neem	0.0^{a}	0.0^{b}	0.4^{a}	0.2^{a}
Ginger	0.1^{a}	0.1^{b}	0.3^{a}	0.3^{a}
Control	0.0^{a}	0.2^{a}	0.4^{a}	0.4^{a}
Pro. of F	0.378	0.0047	0.641	0.378
S.E (±)	0.032	0.051	0.14	0.159
Storage Method				
Pit	0.4^{a}	2.2^{a}	5.6^{a}	3.0^{a}
Floor	0.0^{a}	0.4^{b}	0.7^{b}	1.4^{ab}
Basket	0.0^{a}	0.0^{b}	1.8^{b}	0.0^{b}
Plastic Bag	0.0^{a}	0.0^{b}	2.1^{b}	3.2^{a}
Jute Bag	0.0^{a}	0.0^{b}	1.1^{b}	2.0^{ab}
Carton	0.0^{a}	0.0^{b}	1.2^{b}	0.8^{a}
Prob. of F	0.433	0.0001	0.0088	0.529
S.E (±)	0.045	0.0045	0.23	0.109
Interaction	NS	NS	NS	NS

Values with the same superscript in the same column are not significantly different SE= Standard error, Prob. of F= Probability of F, NS= Not significant

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IMPROVEMENT IN SOIL CHEMICAL PROPERTIES, RELATIVE GROWTH RATE AND BIOMASS YIELD OF OKRA (*Abelmoschus esculentus L.Moench*) AS INFLUENCE BY PPLICATION OF BIOCHAR AND POULTRY MANURE

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ABSTRACT

Field experiments were conducted in the research farm of Faculty of Agriculture, Nasarawa state University Keffi; Lafia campus during 2019 and 2020 rainy season; to evaluate the effect of biochar and poultry manure on soil chemical properties, relative growth rate and biomass yield. The treatments consisted of biochar (0t/ha, 5t/ha and 10t/ha) and poultry manure (0t/ha, 5t/ha, 10t/ha and 15t/ha), replicated three times. The results showed that the soil has high sand particles and the textural class before cropping was sandy loam. Biochar and poultry manure brought about reduction in active acidity of the soil and significantly improved chemical properties of soil in both years of cropping. Application of 10 t ha-1 Biochar and 15 t ha-1 poultry manure had a significant ($p<0.05$) increase in relative growth rates and biomass yield okra in both years of cropping.

Keywords: Improvement, biochar, poultry manure, okra, biomass yield

INTRODUCTION

The problem of infertile soils has become a serious impediment to self-sufficiency in food production in Nigeria (Henao and Baanante 2006). Soil quality reduction due to erosion and continuous cropping on the same piece of land without supplementation of nutrients is a common problem today in Nigeria. The application of organic materials for soil amendment plays important roles in reclaiming and improving the quality of degraded soils. Ayeni, et al., (2012), advocated for the use of organic materials for soil amendment because they are considered less likely to have detrimental effect on physico-chemical properties of soil compared with mineral fertilizers. One feasible measure to increasing soil fertility is the addition of biochar, which is charcoal produced during pyrolysis of organic material. When biochar is used as a soil amendment, it has been reported to boost soil fertility and improve soil quality by reducing soil acidity, increasing moisture holding capacity, attracting more beneficial fungi and microbes, improving cation exchange capacity (CEC), and retaining nutrients in soil (Lehmann and Joseph, 2006).

Poultry manure on other hand is excellent organic manure that contains high levels of N, P, K and other essential nutrients (Farhad et al., 2009). Poultry manure played an important role in improving physical properties of the soil like water retention capacity, porosity, and soil aggregation (Odeleye et al., 2005). It also enhances organic matter deposit and increase biological activities of microorganisms in the soil. In fact, poultry manure has been adjudged to be the most valuable of all manures produced by livestock, this is because the nutrient contents of poultry manure is among the highest of all animal manures, and the use of it as soil amendment for agricultural crops will provide appreciable quantities of all the major plant nutrients (Omisore et.al., 2009).

Okra (Abelmoschus esculentus L. Moench) is one of the most important fruit vegetable crops cultivated and consumed throughout Nigeria. The fresh fruits and leaves are sold daily in the market confirming its value on the basis of land area volume and value (Pathak, 2013). In view of its role and high demand, efforts are being made to sustain and improve the production of okra. However a major limitation to achieving improved okra production is low soil fertility, particularly under continuous cropping. This implies that there is need to raise the soil fertility if increase production of okra is to be achieved. Okra have been reported to have good response to different soil nutrients. The indiscriminate use of mineral fertilizers leads to soil nutrient imbalances in soils, resulting to detrimental effect of the soil properties for optimum crop growth and yield (Mishra and Singh, 2005). Supplementation of mineral fertilizers with organic manures is one of the options for exploiting the crop yield potential and countering the imbalance use of nutrients through chemical fertilizers alone. Most of the available documented researches using biochar on vegetable were carried out in pots in screen houses. There are very few documented results of field experimentation on the use of organic materials especially biochar and poultry manure on production of okra. Therefore the objective of this study is to evaluate the effect of rice husk biochar and poultry manure in upgrading soil chemical properties, relative growth rates and biomass yield of okra

MATERIALS AND METHOD

Description of Experimental Site

The two trials were established during the rainy season of 2019 and 2020 at the Research Farm Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus Nassarawa State. The area lies between latitude 080 33'N, longitude 080 33'E and at an altitude of 181.53m above sea level. The study area falls within southern guinea savanna agroecological zone of Nigeria and the climatic condition of study area is in (table 1).

Table 1: the annual average climatic elements of the study area

Months	Rainfall (mm)	Temp (°C)	Sunshine (Hours)	R.H (%)
January	3.63	36	12.41	30
February	10.26	38	12.33	34
March	30.62	39	12.13	39
April	94.96	37	11.93	54
May	153.16	35	11.67	67
June	194.02	32	10.71	76
July	281.78	29	9.66	83
August	417.92	28	9.18	87
September	364.66	29	9.96	86
October	187.98	32	11.18	78
November	13.29	35	12.35	48
December	3.05	36	12.39	26

Source: NIMET, 2020

Soil and Vegetation

The soil type of the study area is composed of highly leached alfisols with high base saturation. The soil is strongly acidic and has high content of iron and aluminium oxides hence reddish brown in colour with very low organic matter content and low total nitrogen and available phosphate. The vegetation of the study area is that of the southern Guinea Savanna with interspersion of thicket, grassland, trees, fringing woodlands or gallery forest along the streams. The natural vegetation of the area is made up of grasses and some traces of scattered wild and economic trees like Vittellaria paradoxa (Shear butter tree); Parkia spp (locust bean tree); Gmelina arborea (beechwood or gmelina); Anacadium spp (Cashew trees); Magnifera indica (Mango). These trees usually shed off their leaves in the long dry season to conserve the available water (Agbede et al., 2011).

Treatment and Experimental design

The treatments consisted of four application rates of rice husk biochar rates (0t/ha, 5t/ha and 10t/ha) and poultry manure rates (0t/ha, 5t/ha, 10t/ha and 15t/ha). A factorial experiment laid in a Randomized Complete Block Design (RCBD) and replicated three times.

Biochar Production

Rice husk was collected from rice mill for the production of biochar. An improvised kiln was produced which was an empty drum that was perforated but had a cover. The rice husk materials were poured inside the drum half full, then fired was ignited inside the drum and more sawdust materials were added and the drum lid was covered to encourage slow burning and the content in the drum was consistently stirred to enhance uniformity of burning. After 3-4hours the content of drum was poured out and the fire was quenched with water (by sprinkling water on the hot char) and dried in the sun for 2 days (Ndor et al., 2016).

Soil Sampling

The soil samples were initially collected before incorporating biochar and poultry manure for cropping. Then, in 2019 and 2020 soil samples were also collected at a depth of 0-15cm on each plot using soil auger after harvest of okra. Thirty six (36) soil samples were collected in 2019 and another 36 soil samples in 2020. A total of 72 soil samples were collected and properly labeled for easy identification.

Laboratory Analysis of Soil

The soil samples collected were air-dried, and gently crushed, then passed through 2mm sieve to obtain a homogeneous particle size; after which both physical and chemical properties of these soil samples were determined. The particle size investigation was determined by the hydrometer method using sodium hexametaphosphatte and sodium carbonate (Calgon) as the dispersant, and the textural class determination adopted were the USDA textural triangle (Buoyoucos,1951). The organic carbon was determined using the Walkley-Black chromic acid titration method and transform to organic matter by multiplying with 1.72 (Allison 1965). Total nitrogen was determined using Macro-Kjeldahl digestion method as described by Bremner (1965). Available phosphorus was extracted by a solution consisting of 0.025 normal HCl and 0.03 normal NH4F, referred to as Bray-1 extractant (Bray and Kurt, 1945). Soil pH in H2O and KCl were determined using soil – water ratio of 1:2 using glass electrode pH meter (Bates, 1954). Calcium and magnesium were determined using flame atomic absorption spectrometry and the concentration of potassium and sodium was determined using the flame photometer. Cation exchange capacity (CEC) was determined using ammonium acetate method; that is measuring the total amount of a given cation needed to replace all the cation from a soil exchange site and it is expressed in centimoles per 100 gram soil (cmol/100g soil).

Agronomic Practices

The land was cleared, ploughed and harrowed in both locations, then biochar blended poultry manure was incorporated into the plots according to treatment and allowed to stay for two weeks before planting. The Okra seeds were bought from the Lafia market local variety (Dansiriya). Planting spacing of 50cm X 50cm was carried out. Three seeds were sown per hole and later thinned to two plants per stand at two weeks after sowing. Hoe weeding was carried out at 3 and 5 WAS and supplementary weeding was also carried out through hand pulling before the maturity of the crops. The okra plants were sprayed against beetles and caterpillars, by applying Cyperforce which has a systemic and contact action, at the rate of 0.5 litres per hectare (30 mls per 15 litres of water) four times during plant growth period.

Crop Growth Parameters

Five okra plants were randomly sampled from each plot in the field and tagged for observation of some growth parameters (Plant height, Number of leaves per plant, stem diameter, leave area index, relative growth rate, dry and fresh biomass yield).

Leaf Area

$$LA = 0.34\ (LW)^{1.12} \text{ ----------------------- } (1)$$

Where LA = Leaf Area; L= Leaf length; W= Leaf width (Omolaiye et al., 2015)

Relative growth rate

Relative growth rates (g g-^{1}day-^{1}) is calculated by formula of Williams (1946)

$$RGR = \frac{\text{Log } W^1 - \text{Log } W^2}{t^2 - t^1} \text{ ----------- } (2)$$

Where, W1 and W2 are whole plant dry weight at t1and t2respectively; t1 and t2 are time interval in days

Data Analysis

The soil and crop data collected were subjected to analysis of variance using GENSTAT (2008 Ed), and where there was a significant difference; the means were separated using F-LSD at 5% probability level.

RESULTS

Physical and Chemical Properties of the soil before cropping

The result of the chemical analysis and the textural classes of the soil is presented in table 2. The experimental site before cropping was loamy sand, low in nitrogen, phosphorus, potassium, organic matter and also cation exchange capacity. The analysis however, indicated that the soil was acidic in nature with pH of 5.63; high in percent sand fraction (88.00) and also very high in percentage base saturation of 90.94%. While, the pH value for biochar was almost neutral (7.34); total nitrogen was 0.59%; organic carbon 3.78 %; ashes (13.36 gkg-1). Then organic matter was 6.50%; available phosphorus 3.01 cmolkg-1;and low C.E.C of 5.18cmolkg-1but high percentage base saturation of 96.52%. The poultry manure used was very high in both organic matter (35.12%) nitrogen (2.81%) and potassium (4.41%). While the pH was almost neutral (6.81).

Table 1: Results of Soil, Biochar and Poultry manure before incorporating into soil

Soil Properties	Soil of Lafia	Biochar	Poultry manure
Physical properties			
Sand%	88.0	ND	ND
Silt%	3.4	ND	ND
Clay %	8.6	ND	ND
Textural class	Loamy sand	ND	ND
Chemical properties			
pH in H_20	5.63	7.34	6.81
Ashes(gkg^{-1})	ND	13.56	ND
Organic carbon%	13.8	3.78	ND
Organic matter($g\ kg^{-1}$)	2.37	6.50	35.12
Total nitrogen($g\ kg^{-1}$)	2.1	0.59	2.81
P (ppm/$mgkg^{-1}$)	3.01	3.01	0.78
Ca($cmolkg^{-1}$)	3.48	0.31	1.13
Mg($cmolkg^{-1}$)	2.63	1.34	0.51
K($cmolkg^{-1}$)	0.25	3.01	4.41
Na($cmolkg^{-1}$)	0.27	0.52	0.31
EA(cmolkg)	0.66	0.20	ND
CEC($cmolkg^{-1}$)	7.29	5.18	ND
BS%	90.94	96.28	ND

ND = Not determined

Effect of Biochar and Poultry Manure on Chemical Properties and textural classes of soil

Biochar and poultry manure had a significant ($p<0.05$) effect on chemical properties of soil (Table 2) in 2019 cropping season. Increased application rates of all these materials resulted to gradual improvement in most of the chemical properties in the soil except exchange acidity. A reverse trend was observed in exchange acidity, where increased application of biochar and poultry manure resulted in a gradual decrease of exchange acidity. The control in biochar rates had the highest values of exchange acidity of 1.00cmolkg-1 while, the control in poultry manure rates had 0.69 cmolkg-1 as the lowest figure of exchange acidity compare with other rates. Application of 10 t ha-1 biochar produced the highest levels of pH 6.26; organic carbon 1.86%; organic matter 3.20 %; nitrogen 0.35% ; available phosphorus 3.99 cmolkg-1; potassium 0.28 cmolkg-1; C.E.C 6.16 cmolkg-1and the other bases in the soil. Similarly application of 15t ha-1 poultry manure produced the highest levels of pH 6.36; organic carbon 1.69%; organic matter 2.96 %; nitrogen 0.45%; available phosphorus 4.32 cmolkg-1; potassium 0.35cmolkg-1; magnesium 4.15cmolkg-1; calcium 5.12 cmolkg-1 and C.E.C 6.16 cmolkg-1 in the soil after 2019 cropping.

Also, after 2020 cropping season, biochar and poultry manure had a significant ($p<0.05$) effect on chemical properties of soil (Table 2). A reverse trend was also observed in exchange acidity, where increased application of biochar and poultry manure resulted in a gradual decrease of exchange acidity. The control in biochar rates had the highest values of exchange acidity of 0.80cmolkg-1 while, the control in poultry manure rates had 0.67 cmolkg-1 as the lowest figure of exchange acidity compare with other rates. Application of 10 t ha-1 biochar produced the highest levels of pH 6.37; organic carbon 1.68%; organic matter 2.89%; nitrogen 0.42%; available phosphorus 4. 09 cmolkg-1; potassium 0.43 cmolkg-1; calcium 3.96 cmolkg-1; sodium C.E.C 6.16 cmolkg-1 and the other bases in the soil. Finally, application of 15t ha-1 poultry manure produced the highest levels of pH 6.40; organic carbon 1.83%; organic matter 3.15 %; nitrogen 0.49%; available phosphorus 4.46 cmolkg-1; potassium 0.35cmolkg-1; magnesium 4.15cmolkg-1; calcium 5.12 cmolkg-1 and C.E.C 8.15 cmolkg-1 in the soil after 2020 cropping.

Growth Parameters of okra as influenced by biochar and poultry manure

The results on table 4 showed that all plant growth parameters measured were found to be significantly (P<0.05) increased by application of different rates of biochar and poultry manure. Application of 10 t ha-1 rice husk biochar produced the highest number of leaves (13.33 and 14.27) in both 2019 and 2020 cropping season at 7 weeks after planting. The control plots in both 2019 and 2020 cropping season produced the lowest number of okra leaves (11.05 and 9.23) at 7 WAP. The same trend was also observed in application of poultry manure rates in 2019 and 2020 cropping season, where application of 15 t ha-1 poultry manure produced the highest number of okra leaves (17.67 and 15.20) at 7 WAS. The control plots also produced the lowest number of okra leaves (11.10 and 9.62) at 7 WAS. Also, Biochar and poultry manure had a significant (p<0.05) increase on plant height of okra in 2019 and 2020 cropping season. Application of 10 t ha-1 biochar produced the tallest okra plants (25.47 and 25.94cm) in 2019 and 2020 at 7 weeks after sowing (WAS). The control plots in 2019 and 2020 produced dwarf okra plants (12.55 and 10.30cm) at 7 WAS. Similarly, application of 15t ha-1 of poultry manure produced the tallest okra plant (35.73cm and 34.57cm) and the control plots recorded dwarf plants (11.24cm and 10.11) in both years of cropping. Furthermore, Biochar had a significant (p<0.05) increased on leaf area of okra in both 2019 and 2020. Application of 10 t ha-1 biochar produced the widest leaf area (107.52cm2 and 118.18cm2) and the control plots produced smallest leaf area (65.54cm2 and 51.45cm2) in both years of cropping at 7 WAS. Also, application of 15t ha-1 poultry manure produced the widest leaf area (130.53cm2 and 150.48cm2). Finally, poultry manure had a significant (p<0.05) increased on stem girth of okra in both 2019 and 2020. Application of 15 t ha-1 of poultry manure produced the stem girth (3.43cm and 3.54cm), this is statistically at par with other rates of poultry manure applications, but the control plots produced smallest stem girth (1.56cm and 1.78cm) in both years of cropping at 7 WAS. On the other hand, application of biochar did not produced any significant (p<0.05) increase in the stem girth of okra plant.

Biomass production attributes of okra as influenced by biochar and poultry manure

The result on table 4 showed that application of biochar and poultry manure significantly (p<0.05) increase both fresh and dry biomass weights per plant of okra with addition of organic materials into the soil. Application of 10 t ha-1 of biochar produced the highest fresh biomass weight of 783.23g and 962.45g; dry biomass weight of 258.59g and 287.56g in both years. The control rates produced the lowest fresh and dry biomass weight of okra plant. Similarly, application of 15 t ha-1 of poultry manure produced the highest fresh biomass weight of 798.37g and 989.86g; dry biomass weight of 234.98g and 298.69g in both years. The control without any treatment showed a decreasing trend in fresh weight and dry weight throughout the two cropping season.

Table 2: Effect of Biochar and Poultry Manure on Chemical Properties and textural classes of soil in 2019 and 2020

Sample	pH H_20	Org .C%	Org .M%	Total N%	Avail P. cmol/kg	Na+ cmol/kg	K+ cmol/kg	Ca2+ cmol/kg	Mg2+ cmol/kg	CEC cmol/kg	Exch.A .cmol/kg	Sand %	Silt %	Clay %
RHB (t/ha)														
0	5.38	1.42	2.47	0.17	2.90	0.31	0.21	4.21	2.79	4.88	1.00	90.00	3.40	6.60
5	6.11	1.65	2.85	0.20	3.26	0.32	0.27	4.16	3.31	5.64	0.83	90.00	3.40	6.60
10	6.26	1.86	3.20	0.35	3.99	0.32	0.28	4.26	3.58	6.16	0.66	89.00	4.40	6.60
LSD (0.05)	0.12	0.11	0.14	0.05	0.11	0.16	0.14	0.28	0.23	0.13	0.10	0.24	1.00	0.42
PM (t/ha)														
0	6.15	1.62	2.96	0.12	4.06	0.32	0.29	4.96	3.66	6.22	0.69	88.00	5.40	6.60
5	6.15	1.64	3.05	0.26	4.13	0.36	0.29	4.98	3.71	6.65	0.66	88.00	5.40	6.60
10	6.23	1.66	3.09	0.35	4.19	0.37	0.31	5.11	3.96	6.84	0.53	88.00	5.40	6.60
15	6.38	1.69	2.90	0.45	4.32	0.4	0.35	5.12	4.15	7.24	0.51	88.00	5.40	6.60
LSD(0.05)	0.10	0.11	0.03	0.06	0.12	0.13	0.24	0.24	0.13	0.12	0.13	0.21	0.23	0.14
					2020 after cropping									
RHB (t/ha)														
0	6.11	1.68	2.89	0.35	3.21	0.21	0.18	3.46	3.07	7.33	0.80	76.8	5.40	17.80
5	6.23	1.72	2.92	0.35	3.36	0.32	0.23	3.46	3.11	7.34	0.60	72.8	5.40	21.80
10	6.37	1.81	3.10	0.42	4.09	0.32	0.34	3.96	3.56	7.36	0.33	72.8	5.40	21.80
LSD (0.05)	0.10	0.02	0.02	0.24	0.21	0.14	0.08	0.10	0.12	0.02	0.12	0.22	0.24	0.21
PM (t/ha)														
0	6.24	1.82	3.10	0.22	4.11	0.31	0.36	3.96	3.46	7.52	0.67	76.8	5.4	17.80
5	6.27	1.83	3.13	0.32	4.13	0.36	0.38	3.98	3.41	7.65	0.33	72.8	5.4	21.80
10	6.37	1.82	3.20	0.35	4.20	0.37	0.34	4.20	3.16	7.84	0.33	76.8	5.4	17.80
15	6.40	1.83	3.20	0.49	4.46	0.38	0.41	4.62	4.21	8.15	0.17	72.8	5.4	21.80
LSD(0.05)	0.12	0.04	0.05	0.10	0.15	0.15	0.19	0.21	0.12	0.11	0.13	0.21	0.23	0.14

RHB= Rice Husk Biochar PM=Poultry Manure

Table 3. Growth Parameters of okra as influenced by biochar and poultry manure at seven WAP

Treatments(t/ha)	Number of leaves		Plant height (cm)		Stem girth (cm)		Leaf area (cm^2)	
RHB	2019	2020	2019	2020	2019	2020	2019	2020
0	11.05	9.23	12.55	10.30	1.57	1.41	65.54	51.45
5	13.00	13.93	24.10	24.14	1.78	1.79	97.76	116.23
10	13.33	14.27	25.47	25.94	1.89	1.91	107.52	118.18
LSD (0.05)	1.12	1.34	2.15	2.76	0.45	0.64	23.56	28,43
PM								
0	11.10	9.62	14.24	11.10	1.56	1.78	58.24	89.23
5	15.33	14.63	31.40	29.24	3.38	3.42	115.32	124.00
10	15.67	14.80	33.30	32.72	3.34	3.45	120.71	128.43
15	17.67	15.20	35.73	34.57	3.43	3.54	130.53	150.48
LSD (0.05)	1.02	0.30	2.35	2.21	0.16	0.14	32.14	1.732
Interaction								
RHB X PM	NS	NS	NS	NS	NS	NS	NS	NS

RHB= Rice Husk Biochar PM=Poultry Manure

Table 3. Biomass production attributes of okra as influenced by biochar and poultry manure

Treatments(t/ha)	Biomass fresh weight (g)		Biomass dry weight (g)	
RHB	2018	2019	2018	2019
0	582.52	562.46	136.24	128.62
5	614.81	742.23	139.65	139.91
10	783.23	962.45	258.59	287.56
LSD (0.05)	35.24	45.25	60.34	32.34
PM				
0	589.45	578.42	136.24	12.42
5	680.60	720.82	172.68	177.62
10	765.62	903.74	213.79	231.17
15	798.37	989.86	234.98	298.69
LSD (0.05)	32.35	42.32	54.24	36.87
Interaction				
RHB X PM	NS	NS	NS	NS

RHB= Rice Husk Biochar PM=Poultry Manure

Effect of Biochar on Relative Growth Rate of okra

The application of biochar had a significant (P<0.05) increase on the relative growth rate of okra (Fig. 1) at 3, 5 and 7 WAS. Application of 10t ha-1 biochar recorded the relative growth rate of 0.42g at 3WAS; which is higher than other rates and control. At 5WAS application of 10 t ha-1 biochar still performed better than control plots. Finally at 7WAS, application of 10 t ha-1 biochar recorded the highest relative growth rate of 0.9g. This result was statistically at par with the application of 5 t ha-1 biochar, but higher than the control plots.

Effect of poultry manure on Relative Growth Rate of okra

The application of poultry manure had a significant (P<0.05) increase on the relative growth rate of okra (Fig.2) at 5 and 7 WAS. Application of 5t ha-1 poultry manure recorded the highest relative growth rate of 0.08g; which is statically at par with 10 t ha-1 and 15t ha-1 rates of poultry manure. At 7WAS application of 15 t ha-1 of poultry manure produced the highest relative growth of 0.12g compared to other rates.

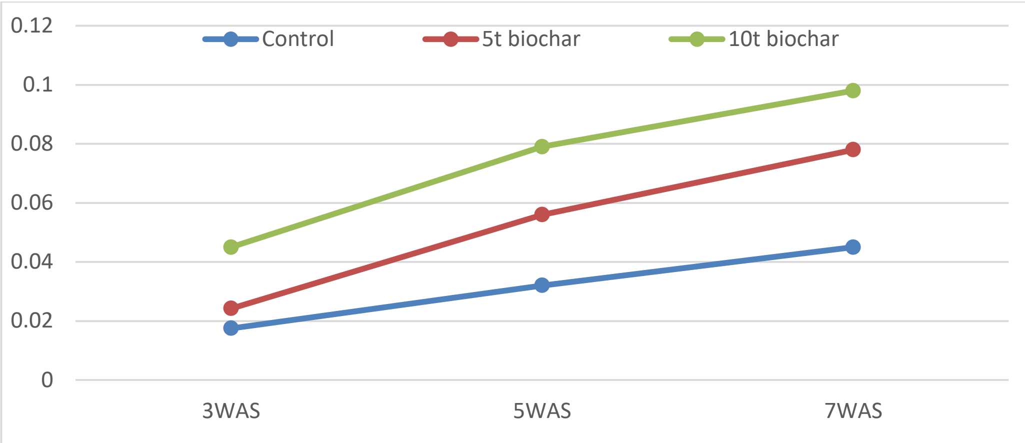

Figure 1: Effect of Biochar on Relative Growth Rate of okra

Figure 2: Effect of poultry manure on Relative Growth Rate of okra

DISCUSSION

The study revealed that the soils of the experimental site is sandy loam, strongly acidic and generally low in soil nutrients and therefore very low in fertility and required nutrients supplementation before crops can be grown. This confirmed the findings of (Jayeoba, et al., 2012) who reported that the soils around Nasarawa state were acidic and low in fertility because of the removal of top soil by process of erosion. The incorporation of biochar and poultry manure brought about the reduction in active acidity of the soil. This may be attributed to the presence of large quantity of ashes in biochar which serve as liming materials (Table 1). This result agrees with the findings of Ndor et al., (2016) who worked on effect of biochar on soil properties and organic carbon sink in degraded soil of southern guinea Savanna Zone, Nigeria. This study also unveiled the efficacy of Biochar and poultry manure as soil amendment materials that significantly help to improve the chemical properties of soil for crop production. This is in conformity with the work of Chan et al., (2007), who reported that Biochar used as a soil amendment, can improve soil fertility and enhance soil quality by reducing soil acidity, increasing moisture holding capacity, entice more beneficial fungi and microbes, enhance cation exchange capacity (CEC), and retaining nutrients in soil. The vigorous performance in vegetative growth (number of leaves, number of branches, plant height) of okra plant exhibited by application of higher rates of biochar mixed with poultry manure in both years compared to biochar application alone; could be attributed to the fact that the soil in the study area consist of higher quantity of sandy particles, low clay content and deficient in some macronutrient (Table 1). When biochar and poultry manure were integrated into the soil it reduces the sizes of the soil pores thereby increasing water holding capacity, increased Cation Exchange Capacity (CEC), and providing a medium for adsorption of minimal plant nutrients and enhance conditions for soil micro-organisms (Sohi et al., 2009). In addition, poultry manure that was used contain high amount of some mineral elements like N P and K (Table 2).

These mineral elements especially nitrogen is responsible for growth of green plants. This explains why amending the soil with biochar and poultry manure brought about visible improvement in the growth performances of okra plant. This is in support of Odeleye et al., (2005), who reported a significant increase in all the growth parameter of okra plant when they used organic and inorganic fertilizer; which is an attestation that okra plants were able to utilize the nutrients in the fertilizer material. Also, the significant improvement in relative growth rate (RGR) of okra as a result of application of biochar and poultry manure. RGR is an indirect measurement of the rate of resource acquisition, and numerous studies have found that increasing crop RGR increases weed suppression (Didon, 2002).

The higher biomass yield as result of application of biochar and poultry manure was attributed to the faster an individual plant accumulates biomass, the more carbon is available to increase growth of roots and shoots for greater access to light and soil nutrients, which in turn enables greater biomass accumulation(Oroka, 2016) .

CONCLUSION

From this study, it can be concluded that 10 t ha-1biochar and 15 t ha-1 poultry manure are the optimal rates of organic materials that can improved chemical properties of soil, good growth and environmentally friendly production of okra.

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PERFORMANCE OF CHICKEN LAYERS FED PROTEIN LEVELS WITH AMINO ACIDS SUPPLEMENTATION

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ABSTRACT

This study evaluated the effects of dietary crude protein with lysine and methionine supplementation to meet the NRC (1994) requirements on the performance of laying hen. Chicken layers at 20 weeks were allotted to 17.5, 15.5, 13.5 and 11.5% crude protein corn-soy diets in a completely randomized design for 12 weeks. Several amino acids were lower than the levels recommended by NRC (1994) as the dietary crude protein level reduced. Feed intake, weight gain, Hen Day Production were significantly (P<0.5) depressed and feed/dozen egg was significantly (P<0.05) in layers fed 11.5% Crude protein diets compared to the other treatments. Feed cost/dozen egg was lower in layers fed 15.5% and 13.5% CP diets compared with those on 17.5% CP diet. The egg quality parameters of layers fed varying levels of dietary protein were similar (P>0.05) across treatments for shell thickness, shell weight, yolk weight and Haugh unit. However, the albumen weight, yolk index and albumen index showed significant (P<0.05) treatment effects among all the groups. Albumen weight was similar (P>0.05) for layers fed 17.5 and 15.5% CP diets but higher (P<0.05) those on 13.5 and 11.5% diets and followed the same trends as the egg weight. Nitrogen output intensity and anthropogenic propensity of the layers fed low protein diets were significantly lower (P<0.05) than in birds fed 17.5% CP. The study concluded that reducing dietary crude protein for laying hens beyond 13.5% had negative effect on performance. To achieve sustainable improvement in nitrogen economy and the quantity of feacal nitrogen of laying hens, 13.5 and 15.5% CP diets could be fed to laying hens. However, there may be need to supplement other amino acids in 13.5% CP diets in layers to correct its negative impact on the egg weight.

Keywords: Laying hens, dietary protein, nitrogen economy, performance

INTRODUCTION

Reducing environmental concerns while maintaining satisfactory production levels are important and current considerations in chicken production. Chicken feeding operations and manure management are important sources of nitrogenous emissions such as; ammonia, nitrous oxide and other oxides of nitrogen. Tackling nitrogenous emissions at nutrition level is an effective strategy for reducing the amount of nitrogen and other nutrients excreted into the environment (Malomo *et al*., 2014). Nutritional strategies for reducing nitrogen excretion in poultry include reduction of protein concentration in diets (Roberts *et al*., 2007; Malomo *et al*., 2013), acidification of diets (Wu *et al*., 2007), dietary inclusion of feed additives (Amon *et al*., 1995) and the use of ideal protein diets in which the limiting amino acids are supplemented with synthetic ones to meet the recommended requirement (Dong *et al*., 2017).

Feeding dietary protein concentrations that are lower than the recommended levels have been reported to enhance protein utilization in laying hens (Novak *et al*., 2006) as well as reduced nitrogen excretion and ammonia emissions (Roberts *et al*., 2007). However, there have been varying reports about the response of layers to these reductions in terms of performance with or without amino acid supplementation. While some studies have demonstrated enhanced laying performance as a result of supplementing low protein diets with amino acids (Blair *et al*., 1999; Dong *et al*., 2017), others did not (Penz Junior and Jensen, 1992). Ji *et al.* (2014) evaluated the effect of amino acid supplemented with varying dietary protein levels (16-18%) on laying hens and recorded similar Hen Day Production (HDP), daily egg mass, feed intake and Feed Conversion Ratio (FCR) between the low and high protein groups during 21-34 weeks of age. They also found that egg weight and nitrogen excretions declined with decreasing dietary protein. Torki *et al*. (2014) also observed similar productive performance and egg quality parameters for layers fed 16.5% CP and those fed low protein (12-15% CP), however, egg weight and egg mass were depressed when dietary protein was further lowered to 10.5%.

Apart from being effective for reducing nitrogen excretion, low protein diets is also a potential means of reducing mineral excretions in poultry production (Hassan *et al*., 2011; Malomo *et al*., 2014). Although information on the mineral contents of poultry manure are available, it has not been stated with respect to dietary protein levels. This study therefore evaluated the effect of feeding varying dietary protein on the performance and nitrogen economy of layers.

MATERIAL AND METHODS

Experimental Birds and Design

A total of one hundred and eighty (180) 20-week old Isa Brown layers were randomly allotted to four experimental diets with varying protein levels, 17.5%, 15.5%, 13.5% and 11.5%. Forty-five (45) laying hens were randomly allotted to these treatments in 3 replicates of 15 each. The experimental diets and water were administered *ad-libitum* to the birds for a study period of 12 weeks. Proximate compositions of the feed and faecal samples were carried out using the methods of AOAC (1990). The amino acid assay of the feed sample was carried out using method of Spackman et al. (1958). All the diets were formulated to meet NRC (1994) recommendations for lysine and methionine, with no adjustments after the proximate analysis. The proximate composition of the experimental diets is as analyzed is shown in Table 1.

Data Collection

The daily feed intake was calculated by subtracting the left over from the amount of feed offered from to the birds. Feed efficiency per dozen eggs was calculated as the ratio between the feed consumed and the number of eggs produced multiplied by 12 (Ojebiyi *et al*., 2018). The egg weight was determined by weighing whole intact eggs on a sensitive scale. Nitrogen retention study was conducted and anthropogenic potential (AP) was calculated according to Bolu *et al*. (2011). Egg quality parameters were measured using the procedures of Park *et al*. (2002) and Ojebiyi *et al*. (2018). Ellerman and Wing (2003)'s formula for emissions intensity was adapted for nitrogen output relative to egg production of layers in this study. Thus, nitrogen output intensity for each treatment of layers in this study was expressed as;

$$NOI = {}^{NO}/_{HDP}$$

Where;
NOI = Nitrogen output intensity (Per unit egg production)
NO = Nitrogen output (g/b/d)
HDP = Hen day Production (%)

RESULTS AND DISCUSSION

Amino acid profiles of layers' diets used in the experiment is presented in Table 2.

Although, attempt was made specifically to balance for methionine and lysine in the experimental diets being the most critical amino acids in a corn and soyabean meal-based diet, it was observed in this study that as dietary protein levels was reduced to 15.5% and below, other amino acids such as arginine, isoleucine, leucine, valine, tyrosine and phenylalanine were lower than the recommended dietary requirements for layers and may become limiting. This finding of increasing number of amino acids becoming lower than the levels recommended by NRC (1994) for laying hens is consistent with those found in earlier studies (Malomo *et al*., 2013, Kidd and Loar II, 2021). According to Burnham (2005), the main reason for poor performance of chickens at some reduced protein levels is because when crude protein concentration is lowered beyond practical levels, the diets should be supplemented with amino acids beyond methionine and lysine.

Performance parameters of layers fed different dietary protein levels are presented in Table 3. Feed intake (g/b/d), average weight gain (g/b/d), and HDP (%) revealed significant (P<0.05) treatment effect with the layers fed 11.5% CP diets significantly lower for layers fed 11.5% compared to other treatments.

Table 1: Composition of experimental layer diets (% DM)

	Dietary protein level			
Ingredients	17.5%	15.5%	13.5%	11.5%
Maize	49.70	51.67	57.40	63.40
Soyabean Meal	21.90	15.43	10.20	4.40
Wheat Bran	16.70	21.10	20.50	20.00
Fish Meal	1.00	1.00	1.00	1.00
Bone Meal	3.00	3.00	3.00	3.00
Lysine	0.10	0.10	0.20	0.40
Methionine	0.10	0.20	0.20	0.30
Salt	0.25	0.25	0.25	0.25
Premix*	0.25	0.25	0.25	0.25
Oyster Shell	7.00	7.00	7.00	7.00
Total	100.00	100.00	100.00	100.00
Composition of Diets on as analyzed basis (%)				
Energy (kcal/kg ME)**	2474.30	2440.60	2503.00	2562.00
Crude Protein	17.36	15.39	13.54	11.40
Crude Fibre	8.23	8.83	8.05	8.53
Ash	7.01	8.42	8.07	6.42
Crude Fat	7.16	5.40	7.01	6.42
DM	92.37	92.00	91.84	92.11

*Supplied the following per kg of diet as specified by the manufacturer: Vitamin A, 12500 IU; Vitamin D_3, 2500 IU; Vitamin E, 50.00 mg; Vitamin K_3, 2.50mg; Vitamin B_1, 3.00 mg; Vitamin B_2, 6.00 mg; Vitamin B_{12}, 0.25 mg; Panthothenic acid, 5.00 mg; Nicotinic acid, 20.00 mg; Folic acid, 1.00 mg; Choline chloride, 300 mg; Manganese, 100 mg; Iron, 50 mg; Zinc, 45 mg; Copper, 2.00 mg; Iodine, 1.55 mg; Cobalt, 0.25 mg; Selenium, 0.1 mg
**Calculated

Table 2: Amino acid profile (%) of chicken layers diets with varying protein levels

Parameter	Dietary protein level (%)				NRC (1994)
	17.5	15.5	13.5	11.5	
Lysine	0.94	0.88	0.82	0.86	0.76
Histidine	0.43	0.36	0.27	0.19	0.19
Arginine	1.06	0.79	0.57	0.40	0.77
Aspartic acid	1.63	1.41	1.01	0.64	NA
Threonine	0.53	0.35	0.25	0.16	0.52
Serine	0.61	0.48	0.34	0.24	NA
Glutamic acid	2.28	1.79	1.35	0.99	NA
Proline	0.57	0.46	0.31	0.24	NA
Glycine	0.69	0.48	0.34	0.29	NA
Cystine	0.22	0.14	0.10	0.08	NA
Valine	0.77	0.53	0.36	0.25	0.77
Methionine	0.44	0.49	0.42	0.50	0.33
Isoleucine	0.57	0.47	0.34	0.26	0.72
Leucine	1.51	1.12	0.65	0.41	0.91
Tyrosine	0.61	0.35	0.28	0.24	NA
Phenylalanine	0.87	0.61	0.46	0.36	0.52

Table 3: Effects of varying dietary protein levels on performance of layers

Parameter	Dietary protein level (%)				SEM
	17.5	15.5	13.5	11.5	
Feed intake (g/bird/day)	109.46[a]	110.43[a]	109.50[a]	106.01[b]	0.40
Average weight gain (g/b/d)	6.31[a]	6.53[a]	6.17[a]	3.22[b]	1.13
Egg weight (g)	52.61[a]	52.44[a]	50.20[b]	49.39[b]	0.37
Hen Day Production (HDP) (%)	77.11[a]	74.87[a]	77.38[a]	63.44[b]	3.01
Feed/dozen egg (kg)	1.76[b]	1.78[b]	1.71[b]	2.02[a]	0.09
Feed cost/dozen egg (₦)	147.38[a]	129.34[b]	127.01[b]	136.78[ab]	6.74

[a,b,c] Values on the same row with different superscripts are significantly different (p<0.05)

Feed/dozen egg (kg) showed significant (P<0.05) treatment effect and were inversely proportional to feed intake and hen weight data. Lowering dietary CP from 17.5% to 13.5% resulted in about 12.2% to 13.8% reduction in cost of feed/dozen egg in the present study. However, lowering dietary CP to 11.5% resulted in marginal reduction in feed cost/dozen egg compared with birds fed 17.5% dietary protein. Lowering dietary protein from 13.5% to 11.5% resulted in marginal increase in cost of feed/dozen egg. Egg weight data was significantly affected by the dietary protein level with laying hens fed 15.5 and 17.5% CP diets recording the best performance, which deviated slightly from the feed intake data. No mortality was recorded in layers fed the experimental diets during the period of the study.

The observed lower feed intake of laying chicken hens on 11.5% CP ration could be as a result of higher concentration of methionine coupled with the high energy:protein ratio in the diet compared to other treatments. According to Rama Rao *et al.* (2011), feed intake decreased linearly and feed efficiency improved nonlinearly (P<0.05) with increasing dietary concentrations of methionine in laying hens. Chicken layers fed 13.5% dietary crude protein with methionine and lysine supplementation had similar performance, except for egg weight, to those on higher protein levels possibly because it is consistent with the ranges of protein requirements for egg production (12.77 – 13.93% CP), egg mass (13.22-14.62% CP) and feed conversion ratio (12.26 – 12.93% CP) as estimated by Torki *et al*. (2014). Lower feed intake in chicken layers fed 11.5% CP diet may have contributed to inferior performance of birds in this treatment as they could not compensate for the deficiency in dietary amino acids.

Significantly declining egg weight as dietary CP was lowered beyond 15.5% implies that laying birds could tolerate dietary crude protein reduction to some extent with no adverse effects as observed; however, reduction of crude protein below 13.5% was detrimental to the birds in this study. This observation suggests that beyond methionine and lysine, other amino acids may be limiting in layers fed low CP diets. Accordingly, if higher egg weight is desired, it may not be adviseable to lower dietary protein level of layers than 15.5% between 20 and 31 weeks of age as shown by the result of this study. Khajali *et al.* (2007) reported that layers can compare in performance when fed diets containing approximately 14 to 15% balanced amino acid with those fed a diet with 17% CP. Adeyemo *et al.* (2012) reported significant depression in HDP, FCR, egg weight and weight gain when dietary protein was reduced from 17% to 14% in laying birds at early production phase and concluded that dietary protein level has direct relationship with performance of laying birds. It has been suggested that increasing the concentration of several nutrients such as methionine, choline, and vitamin B_{12} or combinations of related nutrients such as methionine, choline, vitamin B_{12} and homocystine and choline in laying hens could help improve egg weight (Keshavarz, 2003; Burley *et al*., 2013). Supplementing low protein diets with synthetic amino acids beyond lysine and methionine showed egg weight and egg mass which were similar to the high protein diet (Dong *et al*., 2017). However, this may not always be the case as demonstrated by Keshavarz and Jackson (1992).

Higher feed/dozen egg in birds fed 11.5% CP ration compared with other treatments showed that birds fed 11.5% CP diets were less efficient in the utilization of consumed diets in egg production compared to birds on the other diets. Similarly, increase in cost of feed/dozen egg must have been due to lower HDP in layers that received 11.5% CP diets compared to those on higher protein levels.

No mortality recorded in layers fed the experimental diets during the period of the study may be an indication that layers could tolerate dietary protein reduction up to 11.5% during the first period of lay (week 20 – 31). Bunchusak and Silapason (2005) reported that adding synthetic methionine to low CP diets fed to laying hen aged 24 – 44 weeks resulted in significant reduction of mortality rate compared to the low CP diet without adding methionine and the control group.

The egg quality parameters of layers fed varying dietary protein levels are presented in Table 4. The albumen weight of layers followed similar trends with the egg weight data in the current study. The inferior egg weight of layers fed 13% CP was attributed to lower albumen weight, which may be due to lower availability of amino acids from protein synthesis during the 3 -to- 4h period when the ovum is in the magnum (Penz-Junior and Jensen, 1992).

The Haugh unit is a measure of the freshness of eggs and could be affected by the age of birds as well as storage time and temperature of the eggs (Van Niekerk, 2014). The finding of this study is consistent with that of Babiker *et al.* (2011) who reported that the Haugh units of eggs from laying hens was not affected by the dietary protein level at 22 to 36 weeks of age. Similar yolk weight, shell weight and shell thickness of layers fed varying dietary protein is consistent with the observation of Larbier and Leclercq (1994) that reduced dietary protein inclusion in the diet reduces egg production without affecting egg qualities of the laying bird.

Nitrogen utilization data of layers fed varying levels of dietary protein is presented at Table 5. In this study, nitrogen intake was observed to be directly proportional to the dietary protein level and inversely proportional to energy:protein ratio of the diets. According to Summers (1993), laying hens fed low-protein diet (13% CP) consumed about 26% less nitrogen than birds fed 17% protein diets. However, significantly lower intake in birds fed low protein diets may be explained by the fact that birds regulate their intake according to dietary energy level (Bertechini, 2006).

Table 4: Effects of varying levels of dietary protein on egg quality of chicken layers

Parameter	Dietary protein level (%)				SEM
	17.5	15.5	13.5	11.5	
Shell thickness (mm)	0.31	0.32	0.32	0.32	0.01
Shell weight (g)	5.00	5.33	5.00	5.00	0.26
Yolk weight (g)	11.89	11.94	11.94	11.50	0.32
Albumen weight (g)	34.16^{a}	33.06^{a}	31.22^{b}	31.87^{b}	0.55
Yolk index	4.22^{ab}	4.12^{bc}	4.44^{a}	3.93^{c}	0.07
Albumen index	6.80^{a}	6.20^{b}	6.17^{b}	6.31^{b}	0.13
Haugh unit	82.26	83.93	86.20	85.90	1.26

^{a,b,c} Values on the same row with different superscripts are significantly different ($p<0.05$)

Table 5: Effects of varying levels of dietary protein on nitrogen economy of chicken layers

Parameter	Dietary protein level (%)				SEM
	17.5	15.5	13.5	11.5	
Feacal Nitrogen (%)	3.46^{a}	2.98^{b}	2.93^{bc}	2.83^{c}	0.04
Nitrogen intake (g/b/d)	2.81^{a}	2.50^{ab}	2.18^{b}	1.78^{c}	0.17
Nitrogen output (g/b/d)	1.13^{a}	0.83^{b}	0.72^{b}	0.74^{b}	0.11
Nitrogen retention (%)	57.84^{b}	67.82^{a}	66.27^{a}	57.80^{b}	2.74
N-output intensity	0.015^{a}	0.011^{b}	0.010^{b}	0.012^{b}	0.002
Anthropogenic propensity	4.40^{a}	3.23^{b}	2.80^{c}	2.88^{bc}	0.21

^{a,b,c} Values on the same row with different superscripts are significantly different ($p<0.05$)

Nitrogen output was reduced by 26.6% - 36.3% when dietary protein was varied from 17.5% to 11.5%. The highest level of reduction in N output was observed in layers that consumed 13.5% CP diet in this study. Trend of nitrogen excretion in the present study is consistent with the assertion of Torki *et al*. (2014) and Ji *et al*. (2014) that reducing dietary protein with essential amino acids supplementation showed merit for lowering feacal nitrogen while maintaining acceptable performance for laying hens.

Although nitrogen retention in birds fed 11.5% CP diet was similar to that of birds on 17.5% CP diet, the laying performance of birds on this low protein diet was compromised. Reducing dietary CP from 17.5% to 11.5% lowered Nitrogen Output Intensity (NOI) by 20.0% - 33.3% in laying hens. The lowest NOI was recorded by birds fed 13.5% CP diet. The anthropogenic propensity showed direct relationship with dietary protein level, decreasing as CP is lowered in the diets of the layers. Anthropogenic propensity of layers was reduced by 26.6% - 36.4% as a result of lowering dietary CP from 17.5% to 11.5%. Nitrogen retention data in this study is consistent with the report of Keshavarz and Austic (2004) who reported significantly higher nitrogen retention in layers fed low protein diets supplemented with amino acids. However, according to Joseph *et al.* (2000), inadequate protein intake may result in birds' inability to sustain high level of egg production. Thus, it is possible that layers fed 11.5% CP diets satisfied their energy requirement before consuming adequate protein to sustain similar level of egg production as birds on higher dietary protein regime.

Trend of nitrogen output data in this study demonstrated the effectiveness of dietary CP reduction as a strategy for reducing nitrogenous excretions and consequently, emissions from chicken. This finding is consistent with that of Experiment 1 where nitrogen output reduced as dietary protein level was lowered. Summers (1993) reported that reducing dietary protein from 19% to as low as 5% resulted in a concomitant decrease of up to 50% of nitrogen excretion. He also found that depending on the age of the hens, dietary protein levels as low as 11% resulted in a reduction of up to 40% when compared with a conventional 17% protein corm and soyabean meal diet, with a minimum reduction in egg mass. Nitrogen output intensity was enhanced by reduction in CP level of the diets. The implication of the NOI data obtained in this study is that birds on low CP diets were more efficient in nitrogen output relative to egg production. Anthropogenic propensity of layers fed varying dietary protein levels is consistent with the report of Bolu *et al.* (2011) that in broilers, anthropogenic propensity decreased with dietary CP.

CONCLUSION

Reducing dietary crude protein for layers proved promising as a tool for reducing the quantity of feacal nitrogen available for denitrification. However, care must be taken when reducing dietary protein as other amino acids beyond methionine and lysine could become limiting with detrimental effect on performance and nitrogen economy of layers at some reduced levels. The results of this study revealed that reducing dietary crude protein for laying hens beyond 13.5% had negative effect on performance. To achieve sustainable improvement in nitrogen economy and the quantity of feacal nitrogen of laying hens, 13.5 and 15.5% CP diets could be fed to laying hens. However, there may be need to supplement other amino acids in 13.5% CP diets in layers to correct its negative impact on the egg weight.

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NUTRITIVE VALUE OF FARMER-IDENTIFIED MULTIPURPOSE TREES FOLIAGE AS RABBIT FEED

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ABSTRACT

This study assessed the nutrient composition of multipurpose trees foliage as rabbit feed in Port Harcourt, Nigeria by interviewing 25 rabbit farmers, sampled by Snowballing technique. Foliage samples identified by farmers were analyzed for proximate composition, fiber fractions, minerals, anti-nutrients and amino acids. Data was analyzed in SPSS software using descriptive statistics, ANOVA at 0.1% significance and Duncan multiple range test. Results showed dry matter, crude protein, ether extract, crude fiber, ash, nitrogen free extract, organic matter and digestible energy values ranged from 89.37–90.35%, 17.64–22.13%, 3.53–4.07%, 14.96–21.54%, 8.24–10.66%, 36.95–41.72%, 79.70–81.53% and 7.16–8.87 MJ/kcal, respectively, while NDF, ADF, ADL, hemicellulose and cellulose values ranged from 52.87–58.64%, 38.03–47.09%, 9.87–13.03%, 11.55–16.84% and 26.92–34.06%, respectively. Sodium, calcium, potassium, phosphorus and magnesium contents ranged from 0.367–0.456mg/kg. 0.695–0.621, 1.229–0.968, 0.596–0.542 and 0.504–0.463, respectively, while iron, copper, zinc, manganese and selenium contents ranged from 52.86–56.79 mg/kg, 6.45–5.96 mg/kg, 67.34–65.97 mg/kg, 5.67–5.16 mg/kg and 0.129–0.108 mg/kg, respectively. Trypsin inhibitors, tannin, phytate, oxalate, saponin and alkaloid contents spanned 1.87–5.18mg/g, 0.0031–0.0067mg/g, 0.524–0.678mg/g, 0.229–0.581mg/g, 0.362–0.395mg/g and 0.558–0.678mg/g, respectively. As sole feed for rabbits, all forages were rich in protein, ether extractives, fiber, ash, cellulose, hemicellulose, ADL, ADF, NDF, sodium, potassium, phosphorus, magnesium, copper, selenium, lysine, tryptophan, saponins and oxalates, but low in nitrogen free extractives, organic matter, digestible energy, calcium, iron, zinc, manganese, methionine, alkaloid, phytate, tannin, trypsin inhibitors, protein (*M. indica*) and fiber (*M. oleifera*). Feeding rabbits *M. indica* and *M. oleifera* might need adding protein-rich and fiber-rich sources, respectively. Feeding rabbits any of the forages might require boosting the dietary energy, calcium, iron, zinc, manganese and methionine. Saponins and oxalates toxicity might be far-fetched, except forage consumption is abused.

Key Words: Browse, forage, fiber fractions, proximate composition, minerals, amino acids

INTRODUCTION

Beside grasses, African farmers have been feeding foliage from wild and cultivated trees to livestock in confinement for centuries. The trees and shrubs often have multipurpose functions. Multipurpose trees, also called woody perennials, browse and fodder trees include shrubs, woody plants, bushes, palms, woody grasses such as bamboo and climbing plants such as rattans which are natural or planted (Wood and Burley, 1991), and contribute more than one product and service to a land-use system (Wood and Burley, 1991; Ariga, 1997; Dawson *et al*., 2014). Examples of well-known browse species in Nigeria include *Leucaena leucocephala*, *Gliricidia sepium*, *Acacia albida*, *Ficus elasticoides*, *Mangifera indica*, *Musa spp*, *Spondias mombin*, *Cajanus cajan*, *Tamarindus indica* and *Parkia clappertonian* (Jamala *et al*., 2013).

Multipurpose trees are classified based on the attributes of the plants and their function in agroforestry. The functions of multipurpose trees are numerous. They include bioremediation of problem soils; conservation of ecology; fixing soil nitrogen; aesthetic worth; provision of shade, timber and firewood; and erosion control (Stace, 1998). Also they can serve as wind barriers, live fences, fiber, wildlife habitat, extracts for industrial products, food and medicine for man and animals (Ariga, 1997).

The useful products or by-products from multipurpose trees such as fruits, pods, seeds, nuts, roots, edible twigs and foliage are also invaluable feed resource for animals, either as basal or supplemental diets (Dawson *et al*., 2014). When used as supplements to low quality diets, browse fodder consumption can increase total dry matter and crude protein intake, improve digestibility of low-quality forages, increase survivability of animals, especially, over the dry season, increase live weight gain and overall productivity (Roothaert *et al*., 1998; Atta-Krah, 1990).

Multipurpose trees foliage needs to be high organic matter and nutritive value and available across the year (Stace, 1998). The nutritive value and acceptability of multipurpose trees foliage, especially, in the dry season can be high. Onwuka *et al.* (1989) cited by Larbi *et al*. (1996) reported that in the dry season, some indigenous Nigerian browses contain 23.4–30% crude protein compared to 3–10% in mature grasses (Atta-Krah, 1990; Jamala *et al*., 2013) and high levels of calcium, sodium, zinc and iron and sulphur which are deficient in many grasses (Atta-Krah, 1990 Harsh, 2006; Jamala *et al*., 2013). More so, compared to grasses, browse leaves remain green all year round, even in drought, due to their deep root system that taps water beyond the roots of grasses (Jamala *et al*., 2013). Finally, browse plants are found in all agroecological zones of Nigeria, though, available species differ from one region to another (Larbi *et al*., 1996). In all, multipurpose trees have the potential to fill the grass supply gap caused by droughts and annual dry seasons (Atta-Krah, 1990).

Nevertheless, there could be challenges in using multipurpose trees foliage as rabbit feed. Most of the foliage contain anti-nutritional factors which protect the trees from herbivore and pest attacks (Makkar *et al*., 1995). Those factors may be lethal or obstruct nutrient absorption by the consuming animals (Paterson, 1993). Also, varieties of the trees that are suitable for diverse agro-ecological zones are few, while cultivated multipurpose trees seeds are scarce as farmers have poor knowledge and skills needed to cultivate them (Franzel *et al*., 2014). More so, their management and utilization falls between Forestry and Pasture Agronomy disciplines which exacerbate their neglect and underutilization (Gutteridge and Shelton, 1998). Most of these challenges have been or are been resolved. Diverse species of multipurpose trees fit for nutritional needs of livestock species in certain agro-ecological zones are being developed (Franzel *et al*., 2014), while potential negative effects on rabbits consuming foliage rich in anti-nutritional factors have been difficult to prove (Kadzere, 1995).

In many parts of Nigeria, trees foliage is mostly harvested and fed to ruminant animals such as goats (Larbi *et al*., 1996). Also, most research works on the use of multipurpose trees foliage as livestock fodder are focused on ruminants, especially goats, in dry areas (Larbi *et al*., 1996) and rarely on rabbits. Furthermore, attention has been fixated on few tree species even though the screening of more species to diversify the feed resource base is necessary (Solorio Sanchez and Solorio Sánchez, 2002). Notwithstanding this lack of attention to rabbit nutrition using multipurpose trees foliage, different multipurpose trees indigenous to each agro-ecological zone of Nigeria are fed to rabbits by farmers using indigenous knowledge. Formalizing indigenous knowledge of using multipurpose trees foliage as feed for rabbits, whose digestive system, sits between ruminants and non-ruminants and which face the same challenge of low availability of fresh and nutritious fodder in the dry season, needs to be vigorously explored.

The rabbit is a suitable animal for these types of studies since they are natural browsers; chewing different plants in the wild to meet their nutrient requirements (Salem *et al*., 2011). Also, foliage can constitute 80% of rabbit dietary intake for optimal dental, nutritional and health outcomes in smallholder systems (Speight, 2017). To understand the nutritive value of the multipurpose trees foliage used by local farmers as rabbit feed, the starting point is to assess the chemical composition and fiber fractions of the foliage to be followed by dry matter digestibility and growth trials (Norton, 1998). Hence, this study examined the nutritive value and anti-nutritional factors in multipurpose trees foliage used as feed for rabbits in two Local Government Areas of Rivers State. Results could be useful for innovation in rabbit feeding systems in the study area and similar agro-ecologies.

MATERIALS AND METHODS

The Study Area

This study was conducted in two Local Government Areas (Ikwerre and Obio-Akpor) of Rivers State, Nigeria. The area falls within Greater Port Harcourt City of Rivers State located at latitudes $4^o42'$N and $4^o47'$N and longitudes $6^o55'$E and $7^o08'$E (Dan-Jumbo *et al*., 2018). The projected population of the city as at 2019 was 2,130,000 people engaged in fishing, arable farming, government service and private company jobs which are dependent on petrochemical industry (Demographia, 2019).

Sampling procedure and sample collection

The sample population was smallholder rabbit farmers in the two Local Governments. The multipurpose trees foliage samples were collected from twenty-five rabbit farms; ten from Ikwerre and fifteen from Obio-Akpor. The snowballing method was used to get smallholder rabbit farmers because there was no register of rabbit farms in the Rivers State Agricultural Development Programme office which is responsible for hosting farmers' database. With this method, the farmers were briefed on the objectives of the research and potential benefits to them, if they participated. Later, they were interviewed. The farmers were asked about the forages they feed their rabbits. Multipurpose trees amongst the forages presented were isolated and samples collected. The samples were dried in the oven at 100^oC to a constant weight (AOAC, 2005) for use in all the analyses.

Nutrients and anti-nutritional factors analyses

Proximate composition, fiber fractions, macro-minerals, micro minerals, anti-nutritional factors and amino acids of the multipurpose trees foliage were carried out on the collected samples.

Proximate composition analyses and estimation of organic matter and digestible energy

Dry matter, crude protein, ether extracts, crude fiber, ash, and nitrogen-free extractives were assessed in triplicates using methods described by AOAC (2005). The dry matter was assessed using method 967.08 by putting 2 grams of sample in an oven which was heated to 100°C for 24 hours to desiccate the samples to a constant weight. In case the mass of empty crucible was W_o, the mass of crucible with sample was W_1 and the mass of crucible with oven-dried sample was W_3, percent dry matter was assessed using the formula:

$$\textit{Percent dry matter} = \frac{W3-Wo}{W1-Wo} \times \frac{100}{1}$$

Crude protein was assessed using semi-micro Kjeldahl method which involves digestion, distillation and titration techniques. Crude protein content was calculated through multiplying percentage nitrogen by 6.25 (i.e. % CP= %N×6.25). Fats and oils were assessed using the Soxhlet apparatus process (method 2003.06). Should initial mass of dry Soxhlet flask be W_o and final mass of oven-dried flask + oil was W_1, the percentage fat was obtained by the equation:

$$\textit{Percent ether extract} = \frac{W1-W\,o}{Weight\ of\ sample}\ x\ \frac{100}{1}$$

Ash was assessed by the method 942.05 through burning 2g of a sample in a muffle furnace at 550°C for four hours. Percentage ash was estimated using the equation:

$$\textit{Percent ash} = \frac{Weight\ of\ ash}{Original\ weight\ of\ sample} = \frac{100}{1}$$

Crude fiber content was assessed by method 958.06 using 2g of sample in a fiber flask in which W_1 = mass of oven-dried crucible containing residue and W_2 = mass of cooled crucible containing ash free of carbonaceous material. Percent crude fiber was obtained using equation:

$$\text{Percent fiber} = \frac{W1-W\,2}{Weight\ of\ sample}\ x\ \frac{100}{1}$$

Nitrogen free extractives were estimated by difference through subtracting the total percent moisture, crude protein, ether extract, crude fiber and ash from 100, using the formula:

Nitrogen free extractives (NFE) = 100 – (%Moisture + %CP +%EE + %CF + %Ash) as proffered by Lebas (2013).

Digestible energy (DE) and organic matter (OM) were estimated using the two equations proffered by Lebas (2013): (1) DE=15.627+0.000982 x CP^2+0.0040 x EE^2–0.0114 x Ash^2–0.169 MJ/kg DM. (2) OM = %DM–%Ash, respectively.

Analyses of Minerals

The major elements that were assessed include Na, Ca, P, K and Mg, while the minor elements were Zn, Fe, Cu, Mn and Se. Calcium, potassium and sodium were assessed using method 975.11 and Jenway Digital Flame Photometer of PFP7 Model. Minerals were estimated with the equation: % Ca or % K or % N = Meter reading x slope x dilution factor, where meter reading x slope x dilution factor = concentration in parts per million or milligram per kilogramme. Concentration in % = Concentration in parts per million ÷ 10000. Phosphorus was determined by vanado-molybdate spectrophotometric method 975.16. The concentration of P expressed as percent P was estimated using the formula:

$$Percent\ phosphorus = \frac{Absorbance\ x\ Slope\ x\ Dilution\ factor}{10000}$$

Se, Mg, Cu, Mn, Fe and Zn were analyzed using a digest of ash from Ca and P analyses with Buck 200 Atomic Absorption Spectrophotometer and method 975.23. Meter reading for each element was used to calculate the concentration of each element using the formula:

Element (parts per million) = Meter reading * Slope * Dilution factor while Element (%) = Parts per million ÷ 10000.

Fiber Fractions Analyses

Fiber fractions assessed and estimated were neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose and cellulose as stated by Van Soest (1963). NDF was determined using 1g of dried and milled sample, neutral detergent solution, decaline, and sodium sulphite. NDF value in percentage was estimated by the equation:

$$\%\ NDF = \frac{(Weight\ of\ crucible + Dry\ NDF - Weight\ of\ empyt\ crucible\ )x\ 100}{Weight\ of\ sample}$$

Percent cell soluble constituents = 100 – % NDF
ADF was analyzed using 1g of dried sample, cold sulphate acid-CTAB solution and decaline. Percent ADF was calculated with the equation by Van Soest (1963) as shown:

$$\%\ ADF = \frac{(Weight\ of\ crucible + Dry\ ADF - Weight\ of\ empyt\ crucible\ )x\ 100}{Weight\ of\ sample}$$

% Hemicellulose = % NDF–% ADF, whereas percent cellulose was calculated with the equation:

% Cellulose = % ADF–% ADL. To decide ADL, ADF residue obtained was treated with 72% sulphuric acid and estimated using the equation:

$$\%\ ADL = \frac{W1 - W2\ x\ 100}{Weight\ of\ sample}$$

Wherein W_1= mass of crucible and acid-free residue and W_2= Residue ash mass with mass of crucible.

Analyses of Amino Acids

The amino acid profile of the samples was assessed using methods described by Shahidi *et al.* (1999). The samples were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator, and loaded into the Technicon Sequential Multi-Sample Amino Acid Analyzer using ion-exchange chromatography (Technicon Instruments Corporation, Dublin, Ireland).

Anti-nutritional factors' analyses

Phytates were analyzed using chromatophore reagent according to methods described by Mohammed *et al.* (1986). Tannins were analyzed using the modified Vanidlin-HCL technique stated by Zia-Ul-Haq *et al.* (2007). Saponins were assessed as stated by Shukla and Thakur (1986). Assessment of oxalates was by the processes defined by Tuleun and Patrick (2007).

Data Analyses

The data was collected in triplicates and analyzed using Statistical Package for Social Sciences (SPSS) software, version 16.0 (IBM Corp, 2007). The analyses included descriptive statistics and analyses of variance (ANOVA) for comparison of means at 0.1% level of significance, Duncan Multiple Range Test was used to separate significant means.

RESULTS

Proximate composition of multipurpose trees foliage used as rabbit feed

Five multipurpose trees foliage were identified from the forages presented by the farmers. Those include *Moringa oleifera*, *Vernonia amygdalina*, *Musa paradisiaca*, *Carica papaya Mangifera indica*. The proximate composition of multipurpose trees foliage used as rabbit feed is presented in Table 1. Results show that dry matter, crude protein, ether extract and crude fiber contents ranged from 89.37 (*M. paradisiaca*) to 90.35% (*V. amygdalina*), 17.64 (*M. paradisiaca*) to 22.13% (*M. oleifera*), 3.53 (*M. indica*) to 4.07% (*M. oleifera*) and 14.96 (*M. oleifera*) to 21.54% (*M. indica*), respectively. Also, ash, nitrogen free extract, organic matter and digestible energy values ranged from 8.24 (*M. indica*) to 10.66% (*V. amygdalina*), 36.95 (*V. amygdalina*) to 41.72% (*M. indica*), 79.70 (*V. amygdalina*) to 81.53 % (*M. indica*) and 7.16 (*M. indica*) to 8.87 MJ/kcal (*M. oleifera*), respectively. There were significant differences ($p<0.001$) among multipurpose trees foliage for all the indices measured. Furthermore, the least value ($p<0.001$) for ether extract (*M. indica*) was not different ($p>0.001$) from that of *M. paradisiaca*.

Fiber fractions content in multipurpose trees foliage used as rabbit feed

Table 2 shows the fiber fraction content in multipurpose trees foliage used as rabbit feed. Results indicate there were significant differences ($p<0.001$) among the foliage for all the fiber fractions assessed; neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose and cellulose.

Mangifera indica had the highest ($p<0.001$) NDF (58.64%), ADF (47.09%), ADL (13.03%) and cellulose (34.06%) values while *M. oleifera* had the highest ($p<0.001$) hemicellulose (16.84%). Furthermore, *M. oleifera* had the least ($p<0.001$) ADF (38.03%) and cellulose (26.92%) values, while *V. amygdalina* was the least ($P<0.001$) in NDF (52.87%) and ADL (9.87%) and M. indica had the least ($p<0.001$) hemicellulose (11.55%) content. Except hemicellulose, *M. indica* recorded the highest ($p<0.001$) content for all determined fiber fractions while *M. oleifera* was the richest in hemicellulose.

Macro-minerals content in multipurpose trees foliage used as rabbit feed

Table 3 shows macro-minerals (sodium, calcium, potassium, phosphorus and magnesium) contents of multipurpose tree foliage used as rabbit feed. Results showed significant ($p<0.001$) differences among the foliage for all the macro-minerals determined.

Vernonia amygdalina had the highest ($p<0.001$) sodium content (0.456mg/kg), followed by *Musa paradisiaca* (0.415mg/kg), while *M. oleifera* (0.367mg/kg) had the least. However, the value for *M. paradisiaca* was not different ($p>0.001$) from that recorded for *C. papaya* (0.413mg/kg), while that of *C. papaya*, was also not different ($p>0.001$) from that of *M. indica* (0.409mg/kg). The calcium, potassium, phosphorus and magnesium contents in mg/kg ranged from 0.695–0.621, 1.229–0.968, 0.596–0.542 and 0.504 – 0.463, respectively. For all these parameters, *V. amygdalina* had the highest ($p<0.001$) values. Nevertheless, the highest value of phosphorus recorded for *V. amygdalina* was not different ($p>0.001$) from the value recorded for *M. paradisiaca*. *M. indica* had the least values for calcium, potassium and phosphorus while *M. oleifera* had the least value for magnesium, which was not different ($p>0.001$) from magnesium content of *M. indica*.

Micro-minerals content in multipurpose trees foliage used as rabbit feed

Micro-elements content in multipurpose trees foliage used as rabbit feed are shown in Table 4. Results indicate significant differences (p<0.001) among the foliage for all the assessed micro-minerals (iron, copper, zinc, manganese and selenium). *Moringa oleifera* (52.86 mg/kg) had the least iron content while *M. paradisiaca* (56.79 mg/kg) was the highest. The copper, zinc, manganese and selenium contents in mg/kg ranged from 6.45–5.96, 67.34–65.97, 5.67–5.16 and 0.129 – 0.108, respectively. *Carica papaya* had the least (p<0.001) values for these four micro-elements. The highest (p<0.001) values for copper and zinc were recorded for *M. indica* and *V. amygdalina*, respectively while *M. paradisiaca* was the richest (p<0.001) in manganese and selenium. Furthermore, there were no differences (p>0.001) between the copper contents of *M. oleifera* and that of *V. amygdalina,* zinc contents of *M. oleifera* and *M. paradisiaca*, manganese contents of *M. oleifera and M. indica* and selenium contents of *M. oleifera and V. amygdalina*.

Amino acids content in multipurpose trees foliage used as rabbit feed

The amino acids contents of multipurpose trees foliage used as rabbit feed are presented in Table 5. Results indicate significant differences (p<0.001) in treatment means for all parameters studied (methionine, lysine, and tryptophan). The methionine, lysine and tryptophan contents of the foliage in g/100g protein ranged from 0.396–0.254, 0.889–0.738 and 0.337–0.268, respectively. *Moringa oleifera* was the richest (p<0.001) in all the amino acids assessed while *M. indica* was the poorest. However, the methionine content of *M. oleifera* (0.396) was not different (p>0.001) from that of *V. amygdalina* (0.392).

Anti-nutritional factors content in multipurpose trees foliage used as rabbit feed

Table 6 shows the anti-nutritional factor contents in multipurpose trees foliage used as rabbit feed. Results show significant differences (p<0.001) in treatment means for all anti-nutritional factors (trypsin inhibitors, tannins, phytates, oxalates and saponins) studied. *Moringa oleifera* (5.18mg/g) had the highest (p<0.001) content of trypsin inhibitors, while *M. indica* (1.87mg/g) had the least. Tannins were most abundant (p<0.001) in *M. oleifera* (0.0067mg/g) and least in *M. indica* (0.0031mg/g). *M. indica* (0.678mg/g) had the highest (p<0.001) phytate content, followed by that of *V. amygdalina* (0.561mg/g), while that of *C. papaya* (0.524mg/g) was the least. Nevertheless, the phytate content of *V. amygdalina* was not different (p>0.001) from that of *M. paradisiaca* (0.557mg/g). The highest (p<0.001) oxalate content was in *M. indica* (0.581mg/g) while the least value was recorded for *M. oleifera* (0.229mg/g). However, the value for *C. papaya* (0.469mg/g) was not different (p>0.001) from that of *M. paradisiaca* (0.468mg/g). *Vernonia amygdalina* (0.395mg/g) had the highest content (p<0.001) of saponins, while *C. papaya* (0.362mg/g) had the least. The highest value (p<0.001) of alkaloids was found in *M. oleifera* (0.678mg/g), while the least was in *M. indica* (0.558mg/g).

Table 1: Proximate composition of multipurpose trees foliage used as rabbit feed

Components	Multipurpose trees foliage					SEM (df=4)	*p*-value
	Moringa oleifera	*Vernonia amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
Dry matter (%)	90.19^{b}	90.35^{a}	89.37^{d}	90.21^{b}	89.76^{c}	0.097	***
Crude protein (%)	22.13^{a}	20.84^{b}	17.64^{d}	19.93^{c}	14.74^{e}	0.698	***
Ether extract (%)	4.07^{a}	3.71^{b}	3.60^{cd}	3.63^{bc}	3.53^{d}	0.051	***
Crude fiber (%)	14.96^{e}	18.20^{c}	19.60^{b}	17.84^{d}	21.54^{a}	0.579	***
Ash (%)	8.79^{d}	10.66^{a}	9.85^{b}	9.74^{c}	8.24^{e}	0.227	***
Nitrogen free extract (%)	40.25^{b}	36.95^{e}	38.70^{d}	39.08^{c}	41.72^{a}	0.425	***
Organic matter (%)	81.41^{c}	79.70^{e}	79.54^{d}	80.48^{b}	81.53^{a}	0.222	***
Digestible energy (MJ/kg)	8.87^{a}	8.02^{c}	7.47^{d}	8.05^{b}	7.16^{d}	0.157	***

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom;***Significant at 0.001%*

Table 2: Fiber fractions content in multipurpose trees foliage used as rabbit feed

Fiber fractions (%DM)	Multipurpose trees foliage					*SEM (df=4)*	*p*-value
	Moringa oleifera	*Vernonia Amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
NDF	54.87^{d}	52.87^{e}	57.17^{b}	55.12^{c}	58.64^{a}	0.532	***
ADF	38.03^{e}	40.19^{d}	43.82^{b}	41.05^{c}	47.09^{a}	0.838	***
ADL	11.11^{d}	9.87^{e}	12.39^{b}	11.83^{c}	13.03^{a}	0.291	***
Hemicellulose	16.84^{a}	12.69^{d}	13.35^{c}	14.07^{b}	11.55^{e}	0.475	***
Cellulose	26.92^{e}	13.32^{c}	31.43^{b}	29.23^{d}	34.06^{a}	0.632	***

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom;***Significant at 0.001%; NDF=Neutral detergent fiber; ADF=Acid detergent fiber; ADL=Acid detergent lignin; DM=Dry matter*

Table 3: Macro-minerals content in multipurpose trees foliage used as rabbit feed

Macro-minerals (%)	Multipurpose trees foliage					SEM (df=4)	*p*-value
	Moringa oleifera	*Vernonia amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
Sodium	0.367^{d}	0.456^{a}	0.415^{b}	0.413^{bc}	0.409^{c}	0.0075	***
Calcium	0.667^{d}	0.695^{a}	0.688^{b}	0.682^{c}	0.621^{e}	0.0071	***
Potassium	1.126^{d}	1.229^{a}	1.159^{b}	1.154^{c}	0.968^{e}	0.0231	***
Phosphorus	0.558^{c}	0.596^{a}	0.594^{a}	0.589^{b}	0.542^{d}	0.0058	***
Magnesium	0.459^{d}	0.504^{a}	0.496^{b}	0.487^{c}	0.463^{d}	0.0048	***

*[a,b,c,d,e] Means in the same row with different superscripts are significantly different (p<0.001);); SEM=Standard Error of Mean; df=degree of freedom;***Significant at 0.001%*

Table 4: Micro-minerals content in multipurpose trees foliage used as rabbit feed

Micro-minerals (mg/kg)	Multipurpose trees foliage					SEM (df=4)	*p*-value
	Moringa oleifera	*Vernonia amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
Iron	52.86^{e}	53.04^{d}	56.79^{a}	53.27^{c}	55.11^{b}	0.406	***
Copper	6.09^{c}	6.11^{c}	6.38^{b}	5.96^{d}	6.45^{a}	0.050	***
Zinc	67.12^{b}	67.34^{a}	67.15^{b}	65.97^{d}	68.82^{c}	0.130	***
Manganese	5.46^{c}	5.54^{b}	5.67^{a}	5.16^{d}	5.43^{c}	0.045	***
Selenium	0.122^{b}	0.124^{b}	0.129^{a}	0.108^{d}	0.115^{c}	0.002	***

^{a,b,c,d,e} *Means in the same row with different superscripts are significantly different (p<0.001); SEM=Standard Error of Mean; df=degree of freedom;***Significant at 0.001%*

Table 5: Amino acids content in multipurpose trees foliage used as rabbit feed

Amino acids (g/100g protein)	Multipurpose trees foliage					SEM (df=4)	*p*-value
	Moringa oleifera	*Vernonia amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
Methionine	0.396^{a}	0.392^{a}	0.357^{c}	0.375^{b}	0.254^{d}	0.0140	***
Lysine	0.889^{a}	0.883^{b}	0.824^{d}	0.859^{c}	0.738^{e}	0.0146	***
Tryptophan	0.337^{a}	0.332^{b}	0.305^{d}	0.315^{c}	0.268^{e}	0.0066	***

^{a,b,c,d,e} *Means in the same row with different superscripts are significantly different (p<0.001);); SEM=Standard Error of Mean; df=degree of freedom;***Significant at 0.001%*

Table 6: Anti-nutritional factors content in multipurpose trees foliage used as rabbit feed

Anti-nutrients	Multipurpose trees foliage					SEM (df=4)	*p*-*value*
	Moringa oleifera	*Vernonia amygdalina*	*Musa paradisiaca*	*Carica papaya*	*Mangifera indica*		
Trypsin inhibitors (mg/g)	5.18^{a}	4.92^{b}	2.96^{d}	3.18^{c}	1.87^{e}	0.334	***
Tannins (%)	0.0067^{a}	0.0062^{b}	0.0049^{c}	0.0042^{d}	0.0031^{e}	0.000	***
Phytates (%)	0.538^{c}	0.561^{b}	0.557^{b}	0.524^{d}	0.678^{a}	0.015	***
Oxalates (%)	0.229^{d}	0.459^{c}	0.468^{b}	0.469^{b}	0.581^{a}	0.031	***
Saponins (%)	0.389^{b}	0.395^{a}	0.369^{d}	0.362^{e}	0.378^{c}	0.003	***
Alkaloids (%)	0.678^{a}	0.668^{b}	0.618^{c}	0.609^{d}	0.558^{e}	0.011	***

^{a,b,c,d,e} *Means in the same row with different superscripts are significantly different (p<0.001)*

DISCUSSION

The dry matter contents of multipurpose trees foliage in this study were comparable to those in literature (Kadzere, 1995; Larbi *et al*., 1996). Rabbit feeds should have 89% dry matter (Lebas, 2013). Dry matter obtained in this study for all the forages (89.37–90.35%) was within the normal range, hence, acceptable. The crude protein content of most multipurpose trees foliage range from 14–25% (Devendra, 1992). The crude protein values in this study were within this range. Depending on their physiological state, rabbits require 15-18% dietary crude protein (Lebas, 2013). All crude protein values for the multipurpose trees foliage were higher than the rabbit requirements except *M. indica*. This implies that feeding rabbits only *M. indica* foliage may require supplementation of the foliage with other feed materials rich in crude protein. The ether extract requirement for rabbits is 2.5% (Lebas, 2013). All the ether extract values obtained for the multipurpose trees foliage were higher than the requirement for rabbits. It indicates that feeding any of the trees foliage sole to rabbits might satisfy the lipid requirements of the consuming rabbits. The crude fiber content of multipurpose trees foliage in literature ranges from 15.6–22.6% (Devendra, 1992). The fiber content of all the foliage in this study were within the range reported in literature, except *M. oleifera*, which was lower. Differences observed for *M. oleifera* could be due to the age of the foliage because the older the foliage, the more the crude fiber (Kadzere, 1995). The crude fiber requirement for rabbits is 15% (Lebas, 2013). Crude fiber values obtained in this study were higher than the recommended value except *M. oleifera*. It implies that feeding *M. oleifera* sole to rabbits might require supplementation with other fiber-rich feed materials. The ash contents of the evaluated foliage were comparable to literature values reported for several multipurpose trees foliage (Devendra, 1992). Compared to ash requirement for rabbits of 4–6.5% (MSUBT, 2017), the values obtained in this study for all the foliage were high and may not require supplementation, should any of the foliage be fed sole to rabbits. The dietary nitrogen free extract requirement for rabbits is 43–50% (MSUBT, 2017). The values obtained for all the multipurpose trees foliage were low. This implies that should any of the foliage be fed sole to rabbits, there may be need for supplementation with energy-rich rabbit feed materials. Organic matter of pelleted concentrate diets reported for rabbits by Alvarengam *et al*. (2017) ranged from 86.6–88.8 %. Values obtained in this study were marginally less than the suggested range. Reason could be because the values in this study were from forages while those suggested were obtained from concentrate diets formulated with several ingredients. Nevertheless, using any of these foliage alone as rabbit feed might require supplementing the diets with other feed materials that are rich in organic matter. The range of the digestible energy values was similar to that reported for several multipurpose trees foliage (Devendra, 1992). The digestible energy requirement of rabbits for a single feed is 10 MJoules/kg (Lebas, 2013). Values obtained for all the foliage were lower than recommended values. Therefore, feeding any of these foliage alone to rabbits might require boosting the foliage with energy-rich feed materials to increase the dietary energy content.

The NDF requirement for rabbits is 35% (Lebas, 2013) and may range from 27–42% in practical rabbit diets (Gidenne, 2003). All the foliage had higher NDF values than required for rabbits. This supports reports by Lebas (2013) that non-grass forages and leaves can satisfy 53–123% of dietary NDF requirements for rabbits. It implies that should any of the foliage be fed sole to rabbits, there may be no need for supplementation of the diet with NDF-rich sources. The ADF requirement for rabbits of mixed classes is 17% (Lebas, 2013) and ranges from 16–21 % (Gidenne, 2003). The values obtained in this study were all higher than requirements for rabbits. It thus agrees with Lebas (2013) that non-grass forages and leaves can satisfy 91–335% of dietary ADF required by rabbits. The results indicate that feeding rabbits any of the forages alone may satisfy their requirement for ADF without any need for dietary supplementation with ADF-rich feed materials. The ADL requirement for rabbits is 5.5% (Lebas, 2013). All the foliage had ADL contents higher than the value required for optimal rabbit nutrition. It means that should any of the forages be fed sole to rabbits, their need for ADL will be properly satisfied without dietary inclusion of additional ADL-rich feed material. Generally, forages of any kind contain about 10–25% hemicelluloses on dry matter basis (Gidenne, 2003). Hemicellulose values of all the foliage evaluated in this study were within the normal range for forages. The hemicellulose requirement for rabbits is 10% (Lebas, 2004). All the values obtained for the foliages in this study were higher than this value. Therefore, feeding any of the multipurpose trees foliage to rabbits might satisfy their hemicellulose requirements. Cellulose is 10–30% of dry matter in forages (Gidenne, 2003). The values obtained in this study were within the reported range. The cellulose requirement for rabbits is 11% (Lebas, 2004). All the foliage evaluated in this study had cellulose contents that were higher than the recommended dietary requirements for rabbits. Hence, sole-feeding any of these foliage to rabbits might not require supplementation with cellulose-rich feed materials.

The sodium, calcium, potassium, phosphorus and magnesium requirements in mixed or single feeding regime for rabbits are 0.22, 1.10, 0.6–1.8, 0.5 and 0.04%, respectively (NRC, 1977; Lebas, 2013). Except calcium, all other assessed macro-mineral values were higher than values required in feeds for rabbits. Hence, there could be need for supplementation of rabbit diets with calcium-rich feed materials should any of these foliage be fed sole to rabbits.

The iron, copper, zinc, manganese and selenium requirements of rabbits in mixed and single feeding regime are 100, 5, 70, 8.5 and 0.05 mg/kg (NRC, 1977; De Blas and Mateos, 2020). Compared to these standard values, the values of iron, zinc and manganese in this study were low, while those for copper and selenium were high. It implies that feeding any of the foliage sole to rabbits might require supplementation with other feed materials rich in iron, zinc and manganese for the rabbits to grow to their full potential.

The methionine, lysine and tryptophan requirements for rabbits are 0.6, 0.7, 0.2 g/100g protein, respectively (NRC, 1977). Results from this study of multipurpose trees foliage shows that methionine values were lower than standard requirement while lysine and tryptophan values were higher. Therefore, feeding any of the foliage sole to rabbits might require supplementation of the foliage with feed materials rich in methionine.

Trypsin inhibitors are protease inhibitors and enzymes present in leaves and seeds of crops to defend the plants against pathogens and store plant proteins (Moura and Ryan, 2001). They also degrade proteins and are being explored as signaling molecules in biological activities and diseases management (Srikanth and Chen, 2016). The trypsin inhibitor content of *Myrianthus arboreus* leaves, one of the indigenous Nigerian browse plants is 341.20 mg/100g (Amata, 2010). Compared to this value, those obtained in this study were very low. This agrees with Samtiya *et al*. (2020) that protease inhibitors are most abundant in legumes, less in cereals and trace in others. Since none of the assessed foliage were legumes nor cereals, they may not harm rabbits upon consumption.

Tannins, (condensed and hydrolysable) are polyphenols which easily dissolve in water and occur in grains, legumes, fruits and herbs (Salem *et al*., 2011). Tannic acid can lower feed intake, growth rate, feed efficiency, net metabolizable energy and protein digestibility in animals (Chang *et al*., 1994). Tannin contents of browse foliage from southeastern Nigeria on the average were 0.51% (Okoli *et al*., 2003). According to Al-Mamary *et al*. (2001), a low-tannin (1.4% catechin equivalent) rabbit diet was not toxic while high-tannin (3.5% catechin equivalent) diet could lower live body weight gain and feed conversion ratio. Values obtained in this study were lower than those reported for several trees foliage (Makkar, 1993; Al-Mamary *et al*. 2001; Okoli *et al*., 2003), lower than toxic thresholds and would unlikely be toxic to rabbits, should any of the foliage be fed them sole.

Phytates are salts of phytic acid found in plants, animals and soil. In plants, phytates are common in seed and grains at 0.5–5% w/w (Konietzny and Greiner, 2003). Availability of zinc, iron, calcium, magnesium, manganese and copper from foods of plant origin is low because they are bound to phytates. The phytic acid content of some green leaves such as spinach and sweet potatoes is about 0.07% while that of leguminous seeds and cereal grains range from 0.6–3.87 % and 0.5–0.99 %, respectively (Ravindran *et al*., 1994). The phytin content of some indigenous browse foliage in southeastern Nigeria average 0.0193 % (Okoli *et al*., 2003). Compared to phytate content of browse foliage in Rivers State and Southeastern Nigeria (Okoli *et al*., 2003; Oji *et al*., 2020), the phytate values obtained in this study were low. This low values agree with Maga (1982) and Ravindran *et al*. (1994) that foliage contain only trace amounts of phytates. Feeding any of these forages sole to rabbit might not harm the rabbits but may need supplementation with phosphorus-rich feed materials.

Oxalates bind with minerals such as calcium, magnesium, sodium and potassium, to make them inaccessible to the body by forming of oxalate salts. Oxalate content is more in leaf than stem (Kumar *et al*., 2017). Cattle fed on forage with 2.0 % oxalate develop a negative calcium balance because as dietary amount exceeds normal degradation by microbes, excess oxalates combine with feed calcium to form insoluble calcium oxalate which is unavailable for absorption, leading to hypocalcaemia. Oxalate content of browse plants obtained from parts of Nigeria ranged from 0.00003151 to 0.106.51% (Okukpe and Adeloye, 2011). Compared to these literature values, those obtained in this study were high. Differences could be due to the age of the foliage as Kumar *et al*. (2017) reported that older leaves contain more oxalate than younger ones. In this study, the leaves were plucked at the end of the rainy season, hence, older. Also, oxalate values in this study were lower than the values which may cause harm as reported for cattle (Kumar *et al*., 2017). Hence, rabbits might be fed any of those foliage without harming the animals as excessive consumption of oxalic acid might result in nutritional deficiencies and severe irritation to the lining of the gut (Okukpe and Adeloye, 2011).

Saponins are glycosides containing a polycyclic aglycone moity attached to a carbohydrate and characterized by a bitter taste and foaming properties (Kumar *et al*., 2017). Some properties of saponins include sweetness or bitterness, foaming and emulsifying, pharmacological and medicinal, haemolytic, anti-microbial and insecticidal activities. Saponins reduce the uptake of certain nutrients including glucose and cholesterol at the gut through intra-lumenal physicochemical interaction. In monogastrics, retardation of growth rate, due primarily to reduction in feed intake are some toxicity symptoms (Kumar *et al*., 2017). Compared to values in literature (Gboshe and Ukorebi, 2020), values obtained in this study were high, but, not high enough to cause bloat (Kumar *et al*., 2017), a common syndrome resulting from excess saponin consumption by animals.

Alkaloids are huge and assorted group of chemicals with alkaline characteristics and not less than one nitrogen atom in heterocyclic ring form (Taylor and Hefle, 2017). Alkaloids are used by plants for defense and prevention of herbivory. They are mostly found in *leguminaceae* and have bitter taste, hence, could hamper the consumption of alkaloid-rich feeds (Glencross, 2016). However, most alkaloids are palatable to and preferred by animals though they might interfere with the nervous system and could be toxic when consumed in excess by animals (Lima, 2022). Values recorded in this study were lower than values reported for some browse plants in Rivers State (Oji *et al*., 2020). This could be because foliage examined in this study were not legumes. Hence, toxicity from alkaloids should rabbits consume any of these forages sole may be far-fetched.

CONCLUSION

The dry matter content of all forages were within the normal range while the crude protein, ether extractives, crude fiber, ash, cellulose, hemicellulose, ADL, ADF, NDF, sodium, potassium, phosphorus, magnesium, copper, selenium, lysine, tryptophan contents were higher than recommended for rabbits, except the crude protein content of *M. indica* and *M. oleifera*, whose crude protein and crude fiber, respectively, were lower. Also, the nitrogen free extractives, organic matter, digestible energy, calcium, iron, zinc, manganese and methionine values were less than values recommended for rabbits. More so, the alkaloid, phytate, tannin and trypsin inhibitor contents of all the forages were low, while saponin and oxalates contents were high. We conclude that feeding *M. indica* and *M. oleifera* foliage sole to rabbits might need supplementation with protein-rich and fiber-rich sources, respectively, while using any of the foliage as sole feed for rabbit might require boosting them with sources rich in energy, calcium, iron, zinc, manganese and methionine. Finally, though saponin and oxalate contents were high in all the forages, the risk from disorders associated with excess consumption of these anti-nutrients might be far-fetched, except consumption of the forages as sole feed is abused. This is unlikely in Nigerian smallholder rabbit feeding systems which are high in diet diversity.

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PERFORMANCE AND BLOOD INDICES OF FATTENING YANKASA RAMS FED UREA TREATED GROUNDNUT SHELLS WITH FIBROLYTIC ENZYMES

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ABSTRACT

The trial was carried out to study the effects of feeding urea treated groundnut shells with xylanase and glucanase combinations at various ratios in the rations of fattening Yankasa rams on performance and blood parameters. Sixteen Yankasa rams weighing an average of 17±0.75 kg were managed on a clean floor in well ventilated stalls fitted with individual feeding and water trough. Five rations were compounded to meet the recommended dietary requirements of the rams. The rations were: control (without groundnut shells and enzymes); 50:50 xylanase-glucanase ratio (XGR); 75:25 XGR and 25:75 XGR. The rams were randomly allotted into four treatments groups consisting of four rams per group in a completely randomised design. Feed and water were offered *ad libitum*. Fattening performance, cost/kg feed and blood profile of the rams were studied. Data collected were analysed using GLM procedure of SAS 9.0. Results obtained showed significant difference at $p<0.05$. Weight gained was relatively high ($p<0.05$) in 75:25 XGR (46.49 g/d) group compared to the other enzyme groups, while feed intake increased ($p<0.05$) in the 50:50 XGR (785.30 g/d) group compared to other treatments. However, the least ($p<0.05$) feed conversion ratio was observed in the control (11.34) and 75:25 XGR (14.53) groups. Feed cost/kg was cheaper in the enzyme groups. Packed cell volume values ranged from 22.50–33.50%, Hb (44.50–68.00%), RBC (4.67–8.00 $\times 10^{12}$/L), WBC (6.40–8.67 $\times 10^{9}$/L) across all treatments groups. Most of them were within the normal reference range recommended for healthy sheep and were statistically ($p<0.05$) different. In conclusion, it can be observed that the group of rams receiving 75:25 XGR had better feed efficiency, cost effective and better blood profile compared to the other enzyme groups in the rations of Yankasa rams.

Keywords: feed conversion ratio, feed intake, glucanase, haematology, weight gain, xylanase

INTRODUCTION

Groundnut shells are readily available especially in regions where groundnut farming is one of the major crop grown in that location. They are usually left away to rot and can be seen as huge hips of waste in the dumping sites (Grandawa, 2014). They constitute environmental nuisance such as blocking drainages to cause erosions and when incinerated, pose a hazard of increasing greenhouse emissions which is now a global concern (Honeywell, 2022). When consumed by animals, it has low digestibility and degradability, leading to poor performance of such animals (Millam, 2016).

Groundnut shells are used as feed resources for ruminants and it is attracting the attention of a number of animal nutritionists who want to learn more about it in order to reduce the threat of problems caused by groundnut shells, such as reducing their negative environmental impact, solving the problem of dry season feeding, and lowering production costs of feeds (Abid *et al*., 2020). This will allow low-income farmers to switch between conventional and commercial feeds without affecting the animals' performance. Groundnut shells are easily available and inexpensive, particularly in threshing towns, and can be treated with urea to weaken their fibrous structure and enhance their protein content (Abdel Hameed *et al*., 2013). Because urea alone will not completely improve the use of groundnut shells, supplementing may be beneficial (Millam and Abdu, 2017). Similarly, feed additives such as exogenous fibrolytic enzymes provide a mechanism for addressing such nutritional deficits, which enhances not only the animal's nutrition and consequently growth rate, but also its health and welfare (Yirga, 2015). Exogenous fibrolytic enzymes (EFE) are feed additives that are used in animal nutrition to improve the quality of feed; the performance and health of the animals (Beauchemin *et al*., 2019). Therefore, the present study is aimed at evaluating the performance and haematological indices of fattening Yankasa rams fed urea treated groundnut shells with enzymes combinations.

MATERIALS AND METHODS

Location of the Study

The study was conducted in the small ruminant unit of Adamawa State University (ADSU) Teaching and Research farm, Mubi Local Government Area (LGA). The area lies within the northern-guinea savannah zone of Nigeria. It is located between Latitude 10°16.6’6.9” north of the equator and Latitude 13°16’1.2” east of Greenwich meridian at about 560 meters above sea level. The dry season of the area commences in November and ends in March, while the raining season begins from April and end in late October. The mean annual rainfall is about 1050 mm. The relative humidity is extremely low (20–30%) between January and March but reaches a peak of about 80% in August and September. The maximum temperature can reach up to 40°C particularly in April while the minimum temperature is about 12°C between December and January (Weather Station, 2021).

Source and Processing of Groundnut Shells

The groundnut shells (GNS) used in this study was obtained from a local farmer in Dirbishi ward, Mubi South LGA of Adamawa State. The GNS was milled using a hammer mill fitted with one cm screen, then stored in bags until when required for further use. The processed GNS was treated with urea at 5% (i.e., five grams of urea dissolved in one litre of water to treat one kg of GNS). The solution was uniformly sprayed using watering can on the milled GNS and mixed thoroughly using a shovel on a concrete floor (Can *et al*., 2004). The treated GNS was ensiled in airtight Perdue Improved Cowpea Storage (PICS) double polythene bags for a period of 21 days as described by Al-masri and Guenther (1999). Thereafter, it was spread on polythene sheet to air-dry, bagged and stored before the commencement of the feeding trial.

Ethical Approval

All research protocols and use of animals were approved by Adamawa State University, Institutional Animal Care and Ethics Committee (ADSUIACEC/2020/006). It certifies that the procedures adhere to the International standards on animal use and practice.

Feeding Management and Experimental Design

Sixteen Yankasa rams (from the previous experiment) with an average weight of 17±0.75 kg were used for this of the study. The rams were selected from the previous study. Their experimental pens were properly washed and fumigated. The rams were maintained on a mixture of cowpea and sorghum husk before the commencement of the trial. During this period, they were treated with long lasting antibiotic (Oxytetracycline LA) and ivermectin (Ivomec®) against bacterial infections, internal and external parasite. Before the commencement of the trial, four rams were randomly assigned to a treatment group in a completely randomised design. Each ram was housed individually in a well-ventilated pen with concrete floor equipped with individual water and feed trough. Feed and water were offered *ad libitum* throughout the study. The feed offered were measured using electronic kitchen scale (WH-B05). The daily ration was divided into two portions and supplied at 8:00 and 14:00 hours.

Experimental Rations

Four dietary treatments (Table 1) were formulated for this study. One of the dietary groups was having no groundnut shells and enzyme denoted as control. The other three were urea treated groundnut shells with enzymes combinations at various ratios, thus: xylanase and glucanase at 50:50, 75:25, and 25:75. The enzymes were obtained from RONOZYME® MultiGrain (MG), DSM Nutritional Products Limited, Switzerland; xylanase (endo-1, 4-β-xylanase; EC 3.2.1.8) and glucanase (endo-1, 3 (4)-β-glucanase; EC 3.2.1.6 and endo-1, 4-β-glucanase; EC 3.2.1.4). The enzymes were added according to manufacturer's recommendation.

Data Collection

Feed intake was measured daily while feed-to-gain ration was computed at the end of the trial. The initial weights of the rams were taken at the beginning of the trial using WeiHeng (WH-A series) potable electronic hanging scale (WH-A08) for three consecutive periods. The subsequent weight of the rams was recorded fortnightly. The feeding trial lasted for 90 days.

The cost benefit analysis was carried out to determine the profitability of feeding the experimental rations to the fattening Yankasa rams. Input and products cost were calculated based on the cost of commodities at the prevailing market prices.

At the end of the feeding trial, blood sample were collected from the jugular vein of three rams from each treatment using five millilitre syringe over EDTA (ethylenediamine tetraacetic acid) bottle for packed cell volume (PCV), haemoglobin (Hb), red blood cells (RBC) and white blood cells (WBC) determination; centrifuge bottle for total protein, creatinine and blood urea (BUN) determination; and fluoride oxalate bottle for glucose determination. The samples were taken to the Laboratory Service Department in General Hospital, Mubi for the analysis. The Hb and PCV was determined by acid haematin method (Benjamin, 1985) and Wintrobe's tube (Hawk, 1965), respectively. Determination of blood glucose levels was done by the method of Henry and Stobel (1957). Creatinine was determined according to the methods described by Lamb (1991) and BUN was determined by the method of Tannins and Maylor (1968).

Laboratory and Statistical Analysis

Samples of the experimental rations and faeces was collected and oven dried for proximate composition determination as described by AOAC (2005). The cell wall constituents of the feed and faeces was also determined using the methods of Georing and Van Soest (1970). Urine samples was analysed for nitrogen using the micro Kjeldahl distillation method of AOAC (2005). The analysis was conducted in the Nutrition and Biochemistry Laboratory of the Department of Animal Production, ADSU, Mubi. All data obtained were analysed using the Generalised Linear Models Procedure (PROC GLM) of SAS (2002) in a one-way analysis of variance. The treatment effect was tested and a significant difference between treatment means was established by Dunnett's test.

RESULTS AND DISCUSSION

Table 2 shows the fattening performance of the experimental ration fed to Yankasa rams. The results recorded significant ($p<0.05$) effects on most of the parameters that were considered. The group of rams receiving 75:25 XGR had relatively high weight gain (3.91 kg) and average daily weight gain (46.49 g/d) compared to the other enzyme groups. Significantly ($p<0.05$) higher values for both total feed intake (TFI) and average daily feed intake (ADFI) were recorded in 50:50 XGR (60.47 kg and 785.30 g/d, respectively) compared to other treatments. Feed conversion ratio (FCR) was least significantly ($p<0.05$) in 75:25 XGR (14.53) compared to the other enzyme groups.

The higher result revealed for ADWG in the group of rams receiving 75:25 XGR may be attributed possibly to greater nutrient degradation in the rumen due to enzyme combination (Millam *et al*., 2021), digestion, absorption and utilization of microbial proteins produced in the rumen (Adesogan *et al*., 2019) which resulted in considerably higher live weight gain after the consumption of 75:25 XGR ration. Similarly, observed significant increased feed intake in 50:50 XGR was probably due to the release of sugars caused by the hydrolysis of polysaccharides which may have improved the palatability of the ration (Kholif and Aziz, 2014). Fibrolytic enzymes can also aid the rumen microbes to increase the rate of fibre degradation (Beauchemin *et al*., 2004; Abid *et al*., 2020), thus reducing the rumen fill and increasing voluntary intake of forage (Beauchemin and Holtshausen, 2010; Mendoza *et al*., 2014). Comparable results have been reported earlier by Vallejo *et al*. (2016). One of the critical limitation for the use of GNS in ruminant rations is its low palatability (Millam, 2016), and there seems to be a potential to alleviate this restraint by urea treatment, supplementing it with rapidly fermentable agro-industrial by-product (Sarnklong *et al*., 2010) and EFEs (Millam *et al*., 2020). As the voluntary intake of roughage is increased with EFE, poor quality local resources can be economically and successfully used to produce meat for human consumption. This could contribute widely to decrease production costs in ruminant systems by integrating poor quality roughage and fibrous by-products in ruminant rations (Adesogan *et al*., 2019).

The FCR was least ($p<0.05$) in 75:25 XGR group compared to the other enzyme groups. The result may be attributed to better efficiency resulting from the enzyme combination (Adesogan *et al*., 2019). It may also suggests that efficient feed utilization might be obtained when 75:25 XGR is used which will boost growth when the poor quality status of ruminant feedstuff is addressed (either through chemical processing, use of additives, or any other means) in other to reduce fibre concentration (McDonald *et al*., 2010).

The feed cost/kg was observed to be cheaper in the enzyme rations compared to the control. This implies that it is more economical/cheaper to produce fattened rams with the enzyme rations.

The haematology in fattening Yankasa ram fed experimental rations are shown in Table 4. Significant ($p<0.05$) exist among most of the parameters measured except for basophils. Significantly ($p<0.05$) higher values were observed in the group of rams receiving 50:50 XGR (33.5%) and the control (32.0%) for PCV.

Table 1: Gross composition of experimental diets

Ingredients (kg)	Control	50:50	75:25	25:75
Cowpea husk	40.00	0.00	0.00	0.00
UTGNS	0.00	40.00	40.00	40.00
Maize bran	40.50	38.00	38.00	38.00
CSC	17.50	20.00	20.00	20.00
Bone meal	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50
Enzyme	0.00	0.02	0.02	0.02
Laboratory analysis (%)				
Energy (kcal/kg)	2818.60	3006.50	2890.50	2875.10
Dry matter	98.50	98.50	97.00	96.00
Crude protein	13.50	15.20	15.10	15.40
Ether extract	2.00	1.20	1.00	1.50
Ash	5.40	3.50	5.00	5.30
Nitrogen free extract	60.70	66.20	63.40	61.90
NDF	50.20	52.15	53.28	55.65
ADF	48.54	46.85	45.10	42.09

UTGNS: urea treated groundnut shells, CSC: cotton seed cake, NDF: neutral detergent fibre, ADF: acid detergent fibre, Enzyme combination at various ratios to make up 200 g per tonne

Table 2: Fattening performance of Yankasa rams fed experimental rations

Parameters (kg)	Control	50:50	75:25	25:75	SEM
Initial weight	18.10	18.25	17.38	17.26	0.55^{NS}
Final weight	22.52^{a}	22.13^{ab}	21.29^{b}	20.46^{b}	0.50
Weight gain	4.42^{a}	3.89^{ab}	3.91^{ab}	3.21^{b}	0.39
Average daily weight gain (g)	52.62^{a}	46.25^{ab}	46.49^{ab}	38.15^{b}	4.62
Total feed intake	45.53^{b}	60.47^{a}	45.46^{b}	43.04^{b}	3.88
Average daily feed intake (g)	591.60^{b}	785.30^{a}	570.40^{b}	590.00^{b}	50.44
Feed conversion ratio	11.34^{a}	18.72^{ab}	14.53^{a}	21.39^{b}	2.46
Cost/kg of feed (₦)	54.98	46.53	46.53	46.53	-

^{ab} Mean values with different superscript on same row are significantly ($p<0.05$) different, 50:50, 75:25 and 25:75: enzyme combination ratios, SEM: standard error of means

Table 3: Haematological parameters in fattening Yankasa rams fed experimental rations

Parameters	Control	50:50	75:25	25:75	SEM	Ref. ranges
Packed cell volume (%)	32.00[a]	33.50[a]	27.00[b]	22.50[c]	1.15	27–45
Haemoglobin (%)	62.00[b]	69.00[a]	68.00[a]	68.50[a]	2.31	61.6–102.7
Red blood cell ($\times10^{12}$/L)	9.67[b]	13.00[a]	10.27[b]	10.00[b]	0.40	9–15
White blood cell ($\times10^{9}$/L)	8.10[a]	8.67[a]	8.37[a]	6.40[b]	0.32	4–8
Neutrophil (%)	20.50[c]	21.50[bc]	29.50[a]	23.00[b]	0.99	10–50
Eosinophil (%)	2.00[a]	1.50[ab]	1.00[b]	1.50[ab]	0.25	0–10
Basophil (%)	0.00	0.00	0.00	0.00	0.00[NS]	0–3
Lymphocyte (%)	73.45[a]	73.50[a]	69.00[c]	70.50[b]	0.66	40–55
Monocytes (%)	3.50[b]	3.50[b]	0.50[c]	5.00[a]	0.43	0–6

[abc] Mean values with different superscript on same row are significantly ($p<0.05$) different, 50:50, 75:25 and 25:75: enzyme combination ratios, SEM: standard error of means (Source: Fielder, 2015)

Values recorded for Hb and RBC were significantly higher in 50:50 XGR (68.0% and 8.0×10^{12}/L) compared to other treatments. The WBC measured in this study were higher significantly ($p<0.05$) in the control (8.10×10^{9}/L), 50:50 XGR (8.67×10^{9}/L) and 75:25 XGR (8.37×10^{9}/L) compared to the 25:75 XGR. The differentials of WBC recorded significantly ($p<0.05$) higher values for neutrophils, and eosinophils were higher in 75:25 XGR (29.5%), and control (2.0%), respectively, while lymphocytes were higher significantly in the control (73.45%) and 50:50 XGR (73.50%) while the monocytes was in 25:75 XGR (5.0%) compared to other treatments.

It is quiet noticeable that all parameters measured for haematological indices in this study were all within normal range of values recommended for healthy sheep (Fielder, 2015). The values for PCV ranged from 22.50% to 33.50% which shows that most of the values were within normal range (27–45%) recommended for healthy sheep (Fielder, 2015). Statistically speaking, the PCV values of 50:50 XGR were same with the control, indicating that the total cell concentration of blood of the rams was not affected by the urea treatment of GNS and enzyme combination involved in the ration to cause anaemia or dehydrated during the cause of the study. The observed higher values of PCV may be associated with high nutritional status (Table 1) of the rations (Millam *et al*., 2020). The differences in the PCV values among the treatment groups could also mean that Yankasa rams react to different rations differently (Rahman *et al*., 2018).

The Hb values ranged from 62.00% to 69.00%, and were within normal reference range (61.6–102.7%) recommended for healthy sheep (Fielder 2015). This implies that the observed Hb values of the rams was not affected by urea treatment and enzyme combination involved in the ration. Higher values obtained in the group of rams receiving 50:50 XGR shows that the oxygen carrying capacity of the blood was better in the group than the others (Anya *et al.*, 2018).

Values within normal range ($9–15\times10^{12}$/L) for RBC ranged from 9.67×10^{12}/L to 13.00×10^{12}/L. This points out that the experimental rations would not cause the anaemia to the rams (Aruwayo *et al.*, 2011). Though higher RBC values recorded in the enzyme groups indicate that supplementation of the rations with EFE combinations enhance absorption of iron and salt from the intestine more than the other groups (Osita *et al*., 2018). It was also reported that the quality and amount of red blood cells in the animal's body depend on nutrient availability, state of health and physiological status of the animal (Shittu *et al.*, 2020). Ruminants with good haematological composition are likely to exhibit better performance and productivity, so reports Isaac *et al*. (2013).

Observed values for WBC (6.40–8.67 $\times 10^9$/L) revealed that most of the values were slightly above normal range (4–8 $\times 10^9$/L) recommended for healthy sheep (Fielder, 2015). The relative high increased values in the group of rams receiving 50:50 XGR may be ascribed to high composition of lymphocytes as it forms part of the total WBC count (Portea Medical, 2019). The increased values observed implies that the rams have the potential enough toward off attacks that could cause ill-health more than other treatments (Shittu *et al*., 2020). It may also be as a result of some physiological phenomenon (emotional stress, excitement or strenuous exercise) resulting from the restraining the rams during blood collection, which is known to trigger high WBC production (Portea Medical, 2019). The results were comparable to the results of these authors (Millam *et al*., 2020) who studied blood parameters of sheep and used combined EFEs in their rations.

Regarding the differential count test, neutrophil values (20.50–29.50%) were within normal range of values (10–50%) recommended for healthy sheep (Fielder, 2015). Higher neutrophil values recorded in this study reveals that the group of rams receiving 25:75 XGR rations are safer from infection or not predisposed to infection more than other groups even though they are all within normal reference range of values for sheep (Eclinpath, 2020). The results were comparable to the studies of Njidda *et al*. (2014) while Anya *et al*. (2018) recorded higher values after feeding WAD bucks with cocoa pod husk meal. Values for eosinophil's (1.00–2.00%) were all within normal reference range (0–10%) for healthy sheep (Fielder, 2015) which points towards the animals being safe from parasitic infection because eosinophil's is responsible for combating parasitic infection in the system of the animals (Chen, 2005). Higher values recorded in the control shows that the group are safer from parasitic infection compared to the enzyme groups. Observed values of eosinophil's recorded in this study were comparable with the findings of some authors who studied the haematology of healthy sheep (Egbe-Nwiyi *et al*., 2000; Njidda *et al*., 2014; Amuda and Okunlola, 2018). Lymphocytes have the ability to fight active infection and also remember past infection and move into action quickly when the system is re-infected (Chen, 2005). Lymphocyte values (69.00–73.50%) were all above normal range of values (40–55%) recommended for healthy sheep (Fielder, 2015). The relative high value of lymphocytes in the group of rams receiving 50:50 XGR which may have led to the increased WBC counts might be related to the production of more immune cells (and thus antibodies) that play an important role in defending the biological system against diseases (Osita *et al*., 2018) or an indication that the immune system has a rapid response to the defence mechanism (Beigh *et al*., 2018). The observed values for lymphocytes were comparable with those reported by Amuda and Okunlola (2018). Monocytes values (0.50–5.00%) recorded in this study were within normal reference values (0–6%) recommended for healthy sheep (Fielder,

2015) which shows that there were no problems with immune cell production or free from leukaemia (Beigh *et al*., 2018). Greater values observed in the 25:75 XGR group of rams depicts that they are freer from leukaemia in relation to other treatments. Values observed were comparable to the works of Anya *et al*. (2018) who fed raw and processed cocoa pod husk meal-based diets to WAD bucks.

CONCLUSIONS

The results of this study showed that Yankasa rams could efficiently be fattened using rations containing urea treated groundnut shells and 75:25 xylanase-glucanase combination while maintaining a good health status. Farmers can therefore exploit these findings as it could be cheaper compared to the used of cowpea husk.

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USE OF WASTE FROM PROCESSED FOOD FOR MASS PRODUCTION OF CLUPEIDS (*Sierrathrissa leonensis*) AS FISH MEAL INGREDIENT FOR FEED INDUSTRIES

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ABSTRACT

The use of waste from processed food for raising of clupeids was investigated in Department of Aquaculture and Fisheries Management in Lafia. Campus, Nasarawa Keffi. 300 Clupeids were used for this investigation in 4 treatments of 3 replicates in both concrete and earthen ponds (5m by 5m by 1m). Maize bran, Rice offal, Wheat offal and local brewery waste (Pito waste) were collected, dried and milled to powdered form as treatments. Clupeids were collected from Doma Dam and the water quality parameters were determined. The fish were acclimatized and distributed to the treatment ponds (5 males and 20 females per replicate). Feeding were done twice daily to satiation and the remnants were allowed to remain in the water for growth of plankton. Water management and the protection against predators were enforced. The fish percentage survival rates and mean weight gain were determined at 30days while the populations of fish in each treatment were determined at 90days. ANOVA shown significant difference ($p < 0.05$) in the treatments on percentage weight gain and population of the Clupeids. Pito treatment significantly had the highest percentage weight gain (1304.45) and population of Clupeids (18033) at 90days. Percentage survival rate in treatments were not significantly different ($P > 0.005$) in this study. T-test revealed that the percentage weight gain, survival rate and numbers of fish realized from each treatment at 90days were significantly higher ($p < 0.05$) in earthen ponds compared to concrete tanks. The use of Pito waste for mass production Clupeids in earthen ponds is highly recommended

Keywords: Clupeids, Population, Confinement, Pito waste, Survival rate

INTRODUCTION

Feed is one of the major requirements in the production of farm animals like poultry, cattle, rabbits and fish to mention just few. The major source of protein in the feed comes from both plant and animal. Clupeid are very common in North Central Nigeria water bodies especially around Kanji Dams, River Benue, River Niger and Cross river of Nigeria (Olaosebikan and Raji, 2004) and are mostly used for fish meal rather than human consumption The most acceptable major source of protein feed ingredient comes from fish meal. The fish meal is a processed fish part or whole milled and package after extraction of the oil. Most farm animals feed in the market today are made up of fish meal and fish meal is highly expensive in the market although by proximate analysis, it has a very high value for crude proteins. The availability of this fish meal is another problem of feed manufacturing industries in Nigeria. This research is conducted to provide way of getting the fish meal ingredient of good quality, reliable, available, scientifically approved and affordable from clupeids for feed manufacturing industries in Nigeria.

Clupeids (*Sierrathrissa leonensis)* are small sized fish of about 40mm-108mm in size and they are found in Dams and lakes like River Benue, Kainji Dam and Tiga lakes (Olaosebikan and Raji 2004). They are pelagic fish referred to as Taga rana in Hausa language in the North Central States of Nigeria. The fish are suitable for fish meal and the production will alleviate the problems of fish meal ingredients faced by feed industries around North Central States of Nigeria.
Feed ingredient especially fish meal is one of the most expensive ingredient in feed industries. Although, plant materials can serve as protein, fish meal cannot be total replaced by these plant materials. The mass production of clupeid can alleviate the feed industries of the problem of protein feed ingredient.

The domestication of clupeid in confinement in a large body of water is becoming necessary as there is a gap in supply of fish meal ingredient of feed industries in Nigeria. The mass production of fish meal ingredient will not only provide the feed industries with needed fish ingredient but it will also reduce the cost of production in farm animal in Nigeria, create employment which will engage both the youths, adults and the retirees in Nigeria. These may lead to improvement in standard of living of Nigerian people.

Clupeid (*Sierrathrissa leonensis)* is originally described from Sierra Leone Coastal Rivers and it thrived well in man-made lakes. The fecundity ranged from 94 to 2595 eggs, mature gonads are throughout the year with peaks of activity in February/March and in October/November (Otobo 1979b). *Sierrathrissa leonensis*, have a generation time of only two or three months and mature gonads are found throughout the year due to the advantages of fast maturation and extremely high reproduction rate. (Otobo 1979b). *Sierrathrissa* is almost exclusively planktivorous (Adeniji 1975) and zooplankton are among its main food and it is a facultative feeder - feeding on whatever zooplankton is seasonally available (Otobo 1979b).

The provision of clupeid as fish meal Nigeria is believed to improve quality of feed in our feed industries, increase feed capability of our feed industries, provide employment, improve the farm animals and create wealth for Nigerian people hence this research is apt and needful. The project intends to domesticate Clupeid in confinement and mass produce Clupeid as fish meal for feed industries in Nigeria.

RESEARCH METHODOLOGY

Study Area

The research was carried out in the Department of Aquaculture and Fisheries Management Fish Farm, Shabu-Lafia Campus. Nasarawa State University Keffi. Lafia is Located on Latitude $8^0 35^I$N, Longitude $8^0 32^I$E and altitude 181.53m above the sea level with mean temperature of 30^0C, relative humidity of 40-86% and average day light of 9-12hours. (NIMET, 2011).

Determination of Water Quality Parameters of Fish Collection Sites, Collection and Acclimatization of Experimental Fish

The water quality parameters of the fish collection sites were determined before the collection of the fish for a smooth acclimatization of the fish in experimental water bodies. Collection of the endemic Clupeids in the surrounding water bodies was done with net. Examination of the Clupeids and water quality parameters for the transition to artificial stimulated water body in confinement (earthen ponds) was carried out using water testing kit.

Construction of Ponds for Mass production of Clupeids

Construction of 12 earthen ponds with the use of excavator in high water yielding environment was done for adequate water supply as required for Clupeid production in the experimental area at Faculty of Agriculture, Nasarawa State University, Keffi. The Faculty 12 concrete fish ponds of the same size were also used for this investigation

Experimental Setup of This Experiment

300 clupeids were used in this investigation in 4 treatments of 3 replicates. These setups were done in both concrete ponds and the earthen ponds. All the ponds were of the same size (5m by 5m by 1m). Waste from processed food and local brewery waste (Pito) were collected, processed dry and milled to powdered form with hammer mill. The Clupeids for this experiment were collected from Doma Dam and the water quality parameters of the source of the fish collected were determined. The fish were transferred and acclimatized with aerator before them were distributed to the culture treatment ponds in the stocking rates of 5 males and 20 females per replicate. for both concrete and earthen ponds. Feeding of experimenter fish were done twice daily to satiation and the remnants were allowed to remain in the water to stimulate the growth of phytoplankton and live food zooplankton (*Moina miscrura*) which was inoculated (50 individual/L of water) in both the earthen and concrete ponds (Okunsebor, 2014). Water management and the protection of the pond against predators (use of screen) were enforced. Data were collected for analysis at 30days for survival rate and percentage weight gain while at 90 days, population of fish produced in each treatment were determined.

Data Management and Analysis

The data collected were subjected to descriptive statistics, and one-way analysis of variance ANOVA of STAR statistical package and the various means were separated at 95% degree of confidence.

Plate 1: Preserved experimental Clupeids of the study.

RESULTS

The results of weight gain and percentage survival rate of Clupeids (Plate 1) raised in earthen ponds and concrete ponds is shown in Table I. The results from ANOVA shows that there is significant difference (P<0.05) between the treatments of this experiments. In the mean separation, the highest percentage mean weight gain (1304.45) was treatment Pito (Local brewery waste) and it is significantly higher than all other treatments. However, the least percentage mean weight gain was observed in Rice brain treatment

(1121.34). The treatment (maize bran) and that of the wheat offal were not significantly different ($p > 0.05$) from each other.

The result of the survival rate of Clupeids raise in earthen pond stimulated with waste from processed food is shown in Table 1. The ANOVA shown that there is no significant different ($p > 0.05$) between the treatments. Result of the mean survival rate were significantly the same.

The mean number of fish harvested after 90 days of the treatment to shown in Figure 1. Result of the ANOVA revealed that there were significant different between the treatments. Result of the different means of the number of fish harvested (population) in each treatment shown that treatment Pito (local brewery waste) had the number of individual Clupeid fish (18,033) and it is significantly ($P< 0.05$) higher than other in the treatments. The treatment of rice bran significantly ($p < 0.05$) had the lowest number of individual fish in all the treatments.

The T-test of the percentage weight gain, survival rate and number of harvested Clupeids in raised concrete pond and earthen pond stimulated with processed food waste were significantly different from each other. The one of the earthen pond were significantly higher than the one in the concrete ponds. The water quality parameters of the both the earth and concrete pond are shown in Table 3. ANONA shown that the tested water quality parameters were each not significant different in concrete pond and earthen ponds

Table 1: Weight gain and percentage survival rate of Clupeids raised in earthen pond stimulated with waste from processed food

Parameters	Maize bran	Pito	Rice bran	Wheat offal
Initial weight (g)	0.32^{a}	0.32^{a}	0.31^{a}	0.32^{a}
Final weight (g)	4.32^{b}	4.54^{a}	3.87^{d}	4.12^{c}
Weight gain (g)	4.00^{b}	4.22^{a}	3.55^{d}	3.80^{c}
% Mean weight gain	1250.91^{ab}	1304.45^{a}	1121.34^{c}	1200.34^{b}
% survival rate after one month	97.33^{a}	97.33^{a}	97.33^{a}	97.00^{a}

Mean with the same superscript on the row are not significantly different from each other

Table 2: Weight gain and percentage survival rate of Clupeids raised in concrete ponds stimulated with waste from processed food

Parameters	Maize bran	Pito	Rice bran	Wheat offal
Initial weight (g)	0.32^{a}	0.32^{a}	0.31^{a}	0.32^{a}
Final weight (g)	2.26^{ab}	2.54^{a}	2.02^{b}	2.12^{b}
Weight gain (g)	1.94^{ab}	2.22^{a}	1.70^{b}	1.80^{b}
% Mean weight gain	605.71^{ab}	685.76^{a}	536.49^{b}	568.62^{b}
% survival rate after one month	56.67^{a}	57.67^{a}	56.67^{a}	53.67^{a}

Mean with the same superscript on the row are not significantly different from each other

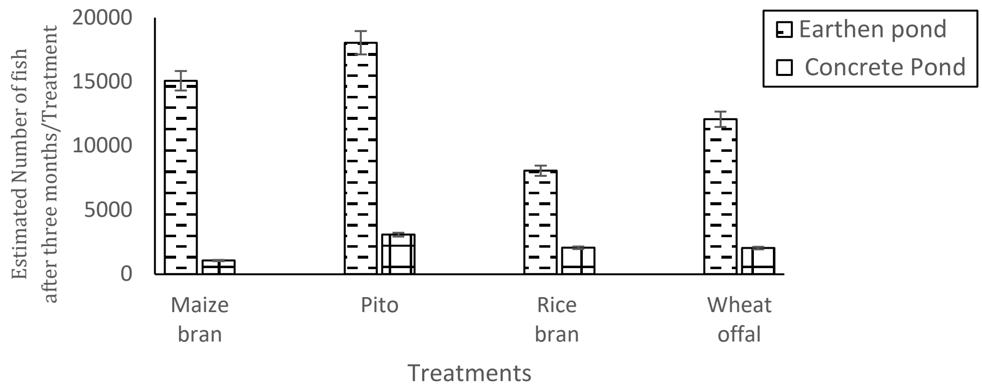

Figure1: Mean Number of fish harvested at 90 days of the experiment in both Earthen and concrete ponds stimulated with agriculture waste from processed food.

Table 3: Water quality parameters of concrete pond and earthen pond of this investigation

Parameters	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Alkalinity mg/L	pH	Water hardness Mg/L	Turbidity cm
Concrete pond	27.56[a] (± 0.21)	4.78[a] (± 0.23)	87.30[a] (± 0.30)	8.20[a] (±0.20)	76.00[a] (± 0.2)	27.00[a] (± 0.12)
Earthen pond	27.57[a] (± 0.22)	4.79[a] (± 0.12)	87.10[a] (± 0.20)	8.10[a] (±0.21)	76.00[a] (± 0.4)	27.00[a] (± 0.11)

DISCUSSION

The survival rate of the Clupeids used for this experiment show that the customized habitats were conducive for to them. The stress of the environment is suspected not to be strong enough to reduce their percentage survival rate. The whole food waste used for the experiment served as feed for the fish while the leftover and the undigested through faecal materials stimulated the processes of nitrate production which faviours the production of phytoplankton. This phytoplankton on its own favours the wellbeing of the various live food zooplankton. *Sierrathrissa* is almost exclusively planktivorous (Adeniji 1975) and zooplankton are among its main food and it is a facultative feeder; feeding on whatever zooplankton is seasonally available (Otobo 1979b. Since the fish is filter feeder and omnivorous in mode of feeding, they easily utilize the plankton for their life advantages. This plankton must have provided the fish with needed nutrient requirements for their lives processes different from most fish are faced with environmental stress that reduces their protein quality (Eyo, 2003).

The percentage weight gain of all the treatment were clear evidence of the feed utilization and the condition surrounding the experimental fish. The differential observed in the weight gain of the experiment are likely due to the nutrient composition of the various treatment feed and the method of processing. The acceptability of the treatment feed and utilization by the fish must have also contributed to the different percentages of weight gain by the fish. The only problem that would have cause challenges to the fish, in form of water quality parameters was minimized as the water quality of the culture medium was normalized by acclimatization. In the experiment, the number of the clupeids were observed to significantly have increased in all the treatment. This also confirmed that the treatments favour the fish wellbeing and the stimulation of the culture medium for sufficient feed in quality and quantity must have enhanced conditions that favoured the reproduction process thereby increases the number of offsprings in culture ponds. *Sierrathrissa leonensis*, have a generation time of only two or three months and mature gonads are found throughout the year due to the advantages of fast maturation and extremely high reproduction rate when conditions are favorable (Otobo 1979b). Pito (Local brewery Waste enhancing more number of offspring is in line with the nutrient capacity, utilization and the ability is stimulate the culture mediums for plankton production.

The results of the test of the percentage weight gain of the earthen pond compared to that of the concrete pond was significantly higher because of the nature of earthen pond. Since the water quality parameters of the concrete pond and that of the earthen pond were not significantly different from each other, there is likely hood of nature of breeding ground as added advantage from the earthen ponds for the production of clupeids

CONCLUSION AND RECOMMENDATION

The freshwater clupeid can be raised using waste food ingredients as feed and as water enrichment for production of plankton for more live feed for filter feeder fish. Clupeids raised in earthen ponds strived better that those of concrete pond under the same water condition. The surviving rate of clupeids on all the waste feed used for this experiment shown above 90% survival rate of the clupeids. The use of earthen pond for culture of Clupeids improved the number of offspring from the parent stock of clupeid fish from 25 to 18,000 individuals within the period of three months.

RECOMMENDATIONS

Domesticated clupeids in earthen ponds are high recommend using waste food ingredients as it promotes nutrient utilization and live food organisms for the fish. The use of Pito Local brewery waste is high recommended for the raising of clupeids in earthen ponds as it favours percentage weight gain, survival rate and number of offspring in experimental ponds.

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