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EDITORIAL

The Editorial Board is happy to release Volume 10(1) of our reputable Journal. This volume is coming under a new Editorial Board and with some new features and framework which will improve the aesthetics of the Journal. The cover has been slightly beautified, including changing the University logo to the new design. This Volume comes with a lot of challenges: first the attention of the Editorial Board was diverted to the hosting of the *First International Conference of Agriculture and Agricultural Technology* (ICAAT), second, the incessant strike action of the *Academic Staff Union of Universities* (ASUU) has always disrupted the smooth operation of the Editorial Board. However, the Editorial Board is putting measures on ground that would ensure that this type of disruptions have minimal effect on the Journal. That is the reason why this volume is being released even during a major industrial action by ASUU.

The Editorial Board is also making frantic efforts to register the Journal with Journal Databases and cataloguing institutions in order to promote the readership of the Journal. Part of the reasons why it has not materialized is our inability to maintain constancy and currency. These are the key requirements of most databases. In that regard, I want to appealed to our contributing Authors to continue to send their papers at any time. The journal production is a circular and continuous process. As from Volume 11, as we prepare to join international institutions, the date of first submission, date of review and date of acceptance of each paper would be part of the metrics of the journal. We may also publish the names of reviewers along with the paper as a form of transparency and promoting integrity in research and publications.

Let me express our profound appreciation to our numerous reviews for sparing their valuable time and scarce resources to review papers for this Volume in a timely manner in spite of their tight schedules. We appeal that they will oblige us this same privilege whenever we approach them for the same favour. I will however appeal to our reviewers to be more critical with the papers since we are dealing with a global audience.

We are very thankful for the support of the Dean of the School, Prof. A. J. Odofin, the Board of the School and the elders of the School for their fatherly roles for all the support. We also express our profound appreciation to our Editorial advisers for their sense of commitment and dedication. We are also appreciative of the role the Vice Chancellor and other Principal Officers in providing the enabling environment in the University for quality Journal publishing.

Editor-in-Chief

Prof. Job N Nmadu

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ENTREPRENEURIAL ACTIVITIES AND TECHNICAL COMPETENCE OF STAFF IN POULTRY PRODUCTION IN SELECTED FARMS IN KWARA STATE, NIGERIA

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ABSTRACT
The study examines the entrepreneurial activities and technical competence of staff in poultry production in selected farms in Kwara State, Nigeria. Proportionate random sampling technique was used to select 147 respondents used for the study based on their sampling frame. Questionnaire was used to elicit information from the respondents and data were analyzed using descriptive statistics, likert scale and Pearson Product Moment Correlation. The result shows that majority of the poultry staff were male (97.5%), married (79.20%), educated (90.8%) with a mean of 3 as average years of experience. 37.5% of the poultry staff were between the age range of 31-35 years. The study also reveals that ability to mobilize and maximize resources and skills for the farm, keep viable farm records, identification of training needs, with mean of 2.0 ($\bar{X} \geq 2.0$) were among the entrepreneurial activities that were highly performed by the poultry staff. The result further reveal that poultry staff were very competent in handling of improved breeding stocks, brooding operation, vaccination, use of drugs, record keeping, and feed ingredients in the study area however untimely availability of good day old chicks, high cost of vaccination and drugs and high cost of feed ($\bar{X} \geq 2.0$) were the major setback affecting poultry production in the study area. The study concludes that in spite of high entrepreneurial activities and high competency observed in poultry staff, there are major setbacks affecting poultry production in the study area. The study therefore recommends that vaccines and drugs for poultry and other veterinary use should be subsidized by government. Moreover, capacity training and seminars for poultry staff should be done to enable them cope with the challenges of modern poultry farming.

Key words: Entrepreneurial Activities, Technical Competence, Poultry, Staff, Kwara State

INTRODUCTION

Entrepreneurship is the process of identifying an opportunity related to needs and satisfaction and converting it to value yielding (Soyibo, 2006). It is referred to as the creation of an innovative business with the aim to create and maximise wealth under conditions of risk (Daft &Marcic, 2007). Achievement in a farming enterprise however, depends on skills at the disposal of the farm entrepreneur. For someone to be a successful entrepreneur, some important skill and characteristic will be exhibited. Skills or competencies according to Vreyens and Shaker (2005) are observable abilities that manifest from an individual indicating how to do something. Skills are an important means to increasing incomes and sustainable livelihoods for the poor (World Bank, 2004). According to Eskola and Gasperini (2010) skills development ''is central to improving rural productivity, employability and income-earning opportunities, enhancing food security and promoting environmentally sustainable rural development and livelihoods''. Moreover, Poultry farmers equally need technical competence in poultry enterprise in areas of animal health, poultry house management, sanitation, vaccines, drugs, feeds and feed formulations among others. Onuka and Olaitan (2007) found that poultry producers need skills for daily inspection and sanitary of the farm, proper feeding management of resources like feeds and keeping records of farm activities. Poultry offers the greatest scope of increasing the quantity and quality of animal protein in Nigeria as poultry meat and eggs account for about 30% of total livestock output of which eggs account for over 80% (Evbuomowan, 2005). Moreover, Ezeigbe (2010) stressed further that poultry production enjoys high interest among livestock production and the meat has high demand in Nigerian markets because of its nutritional content. However, Poor skills development has been reported as a hindrance to profitable and sustainable poultry enterprises. Findings by Mlozi *et al.,* (2003) confirmed that the skills and training required for improving poultry management was lacking and hence could not enhance poultry production. Training is therefore needed to bridge the gap between 'what is' and 'what should be' in terms of incumbent knowledge, skills, attitude and behaviour for a particular situation at a particular time (Solomon, 2008). McElwee (2005) asserted that the development of the entrepreneurial skills and technical competence of poultry farmers is a significant issue which needs to be addressed by all stakeholders in the agricultural socio-economic network. In view of this, there is a need to carry out studies so as to identify the entrepreneurial skills and

technical competence possessed by the operators and the extent of utilizing them for managing poultry enterprises, with a view to enhance production activities and output maximization. Thus, the study sought to address the following objectives;

(i) Describe the socioeconomic characteristics of the poultry farmers,

(ii) Investigate the entrepreneurial activities performed by poultry staff

(iii) ascertain the competence level of poultry staff and

(iv) identify the constraints to poultry production in the study area.

HYPOTHESIS FOR THE STUDY

Ho_1: There is no significant relationship between some selected socioeconomic characteristics and the competence level of poultry farmers**.**

METHODOLOGY

The study area: The study was carried out in Kwara State, Nigeria. The state is located in the North Central Nigeria and it has a population of about 3,192,893 (NPC, 2017). Kwara State is located between parallels110 71´ and 110 45´ and 6 0 40´East longitude, covering 36,825km2(14,218 sq miles) and coordinates 80 300N 5000E (Ogunlade *et al* 2009). It lies exclusively within a tropical hinterland. It also has an estimated figure of 203,833 farm families with the majority living in rural areas. The state experiences both the wet and dry seasons each lasting for about six months. The raining season starts from March and end in October while the dry season begins in November and ends in early March. The total annual rainfall in the state ranges from 800 mm to 1,200 mm in the northwest and 1,000 mm to 1,500 mm in the southeast. The state has a mean annual temperature ranging between 30 – 35 ºC and a relative humidity of 60% on the average. The area is located within the Guinea Savanna. The average height is about 20-40cm. Finger like extension of the tropical rainforest occurs in the state and this is called Gallery forest (Emielu, 1999). Climatic conditions of tropical wet and dry climate permits the growth of export tree crops (like cocoa, oil palm, etc), root crops (like yam, cassava, and cocoyam) and grain crops (like maize, rice, sorghum, etc). Kwara State is divided into four Agricultural zones by the Kwara State. The state cultivates food crops such as maize, cassava, banana, cocoyam, onion, fruits, sweet potatoes, vegetables and livestock such as goat, cattle, sheep, fish, pig and poultry (such as local chicken, Ostrich, quail, layer, broiler etc).The target population for this study was staff of poultry farms in Kwara State.

Sampling procedure: A two stage sampling procedure was used in this study. The first stage involves purposive sampling of three farms in Kwara state based on their size, staff capacity and various units available in the farms. Therefore, Yammfy farm Offa, Fabis farm Ilorin and Daynte farm Ajase- Ipo, were chosen. The second stage involves the proportionate random sampling of the poultry staff from each of the farm based on their staff strength. Therefore, based on the sampling frame obtained from each farm percentages ranging from 10% to 20% were taken from each farm with staff strength ranging between 175 to 650 members to give a sample size of 147 respondents. However, out of 147 questionnaires administered, only 120 were completely filled and useful for data analysis.

Table 1: Sampling procedure and sample size of poultry staff used for the study

Selected farms	Staff strength	Sample size
Yammfy farms	650	10 % = 65
Daynte farms	315	15 % = 47
Fabis farms	175	20 % = 35
Total	1140	147

Source: Data Analysis, 2016

Data Analysis

Descriptive statistics was used to examine the socio economic characteristics of poultry farmers while Pearson Products Moment Correlation was used to test the hypothesis.

A 3 point Likert scale was adopted for measuring the entrepreneurial activities performed by poultry staff in the study area. From literature, twenty entrepreneurial activities were identified. Respondents were asked to indicate their level on the scale as Low, Moderate and High with the score ranging from 1-3. The cut-off point was 2. Therefore any activities having mean that is 2 and above 2 is considered as major entrepreneurial activities that the respondents are involved in, whereas any activities having mean lower than 2 is considered as minor entrepreneurial activities that the respondents are involved in.

A 4 point Likert type scale was adopted for measuring level of competence of poultry staff in the study area. Area of technical competency consists of twenty poultry tasks that cover broilers, layers, feed mill, and vaccination among others. Respondents were asked to indicate their level of competence on the scale of not skilled, moderate skilled, skilled and highly skilled with scores ranging from 1- 4.The cut-off point was 2.5.Therefore, any technique having mean lower than 2.5 is considered as inadequate skill. However, any technique having mean 2.5 and above 2.5 is considered as adequate skill and signifies as competence.

A 3 point Likert type scale was adopted for measuring the constraints faced by poultry staff in the study area. From literature, twenty constraints facing the poultry enterprise have been identified. Respondents were asked to indicate the constraints they faced on a scale of not severe, severe and very severe with scores ranging from 1-3. The cut-off

point was 2. Therefore, any constraint having a mean of 2 and above 2 was considered as a major constraints, while any constraints having below 2 was considered as minor constraints.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents: Table 2 shows the socio-economic characteristics of the respondents selected for the study. It shows that majority of the respondents were within the age range of 26-30 years, 31-35years and 36-40 years (85.83%). This implies that majority of the respondents were still in their productive age and are capable to undergo the risk of entrepreneur. This result is in line with Bekele (2005) who found out among the subsistent farmers in eastern Ethiopia that this age categories are economically active groups. Majority of the respondents were married (79.17%), male (90.83%), literate (90.83%) and have 1-5 years of experience (81.67%). This implies that the poultry staffs were fairly educated and literacy level among the respondents may positively affects the entrepreneurial activities and competency level of the respondents in the study area. However, this contradicts the findings of Omotesho *et al.,* 2012) who reported poor education among agricultural extension officers in Kwara state. Majority (69.17%) of the respondent did not belong to any poultry association and 43.33% of the respondents receive a salary of ₦30,000-₦39,000 monthly.

Entrepreneurial activities of the poultry staff: Table 3 presents the results on entrepreneurial activities of the poultry staff. The finding shows overwhelming positive results towards entrepreneurial skills of poultry staff in the study areas.

The table shows that ability to account for all the units of the poultry farm (layers, broilers, feed mill etc) ($\bar{X}$=3.37) was ranked first as major entrepreneurial activities carried out by the respondents. This may be because of periodic evaluation or auditing of farm activities which will show whether all the units in the farm are making progress or not and make necessary adjustment where necessary. Ability to mobilize and maximize resources and skills for the farm ($\bar{X}$=2.95) which ranked second was another major entrepreneurial activities carried out by the respondents. This may be because of the fact that entrepreneur resource management is very crucial to poultry production. This goes with the view of Sonaiya and Swan (2004) who suggested that income generation and maximization of resources is the primary goal of poultry keeping. Ability to keep viable farm records ($\bar{X}$ =2.92) ranked third was another major entrepreneurial activity performed by the respondents. This may be because of the fact that record keeping will guide an entrepreneur and can show whether an enterprise is making progress consistently or not. Good communication and inter personal relationships with customers ($\bar{X}$=2.90) ranked 4th was a major entrepreneurial activity carried out by the respondents. This may be because of the fact that adequate communication between the staff and the customers will enhance the sustenance of customers to the poultry farms and can even boost the performance of the staff.

Ability to prepare farm budgets and ability to prepare farm financial statements ($\bar{X}$=2.88), Ability to prepare farm financial statements ($\bar{X}$=2.88) and ability to correctly identify and correct production problems ($\bar{X}$=2.88) ranked 5thwere also major entrepreneurial activities the respondents were involved. This may be as a result of the importance of farm budgets and financial statements in the farm activities which are part of the basic requirements in obtaining credit facilities from any financial institutions and a guide in the day to day financial spending of the farm. Moreover, timely identifying and correcting production problem can reduce the risk associated with poultry production. This finding is in support of Hellin *etal*, (2005) who reported that understanding of poultry functioning and marketing structure is a prerequisite for developing market opportunities for rural households and could be used to inform policy makers and development of workers in considering the commercial and institutional environment in which poultry farmers have to operate. However, the ability to organize seminars and training for staff at different units of poultry farm ($\bar{X}$=1.63) was observed as one of the entrepreneurial activities hardly involved in by the respondents. This may be because of financial commitment involved in organizing such trainings for the staff. This is against the findings of Sherif (2005) who opined that entrepreneurship training/education that exposes farmers to life applicable issues is capable of helping the farmers in adoption of new management practices and strengthen their confidence and ability to risk and accept a new technology. Besides, Badi and Badi (2006) ascertained that entrepreneurship education/training provides cultural, social and technological awareness.

Competency level of the poultry staff in farm operations: Table 4 presents the results on level of competence of the poultry staff in farm operations. The finding shows overwhelming positive results towards level of competence of poultry staff in the study areas. The table shows that activity of disease diagnosis and identifying the percentage of feed ingredients were ranked first ($\bar{X}$=3.83). This implies that poultry staffs possess adequate skills in diseases

diagnosis and feed ingredients. This might be because of the importance of a good and balance feed ration in the poultry production enterprise in which any compromise in the formulation of the feed ingredients in the right proportion can create problem in the flock. Likewise a quick and easy disease diagnosis will prevent disease outbreak and reduce mortality. Feed formulation ranked third was another area of poultry enterprise that poultry staffs possess adequate skills ($\overline{X}$=3.79). This might be as a result of importance of good feed to poultry management. Writing of monthly report ranked 4th was another poultry activity that poultry staffs were highly skilled ($\overline{X}$ =3.48). This might be as a result of importance of report writing as part of record keeping in poultry enterprise which can serve as a reference material for past farm activities. Use of improved breeding stocks ranked 5th was another area of poultry enterprise that poultry staffs were highly competent to handle. ($\overline{X}$=2.99). Other areas of poultry enterprise that poultry staffs were highly competent to handle include vaccination ($\overline{X}$=2.98) use of drugs ($\overline{X}$=2.88), Debeaking, culling of birds ($\overline{X}$=2.88), egg collection and packing ($\overline{X}$=2.80) among others. This finding agrees with Emma and Hassan (2010) whose study revealed that factors of production such as price of day- old chicks, price of hens, mortality cost, vaccines and drugs and labour cost represented the most total cost of production. However, table 4 further shows that Poultry staffs do not possess adequate skills in gutter management ($\overline{X}$=2.46), weighing of feed ($\overline{X}$=2.27) and sanitation of farm environments ($\overline{X}$=1.82).

Constraints faced by poultry staff: Table 5 shows that all the constraints identified were encountered by the respondents in the study area, however, the level and extent of severity of the constraint varie. The table shows eight major constraints (mean above 2.0) identified in the study areas in which high cost of vaccines and drugs was ranked first ($\overline{X}$ =2.78), inadequate capital was ranked second (($\overline{X}$ =2.63), Untimely availability of good day old chicks was ranked third, ($\overline{X}$=2.56), high cost of feed was ranked fourth ($\overline{X}$=2.46), financial problem was ranked fifth($\overline{X}$=2.33), , pest and diseases attack was ranked sixth($\overline{X}$=2.23), lack of access to credit facilities was ranked seventh ($\overline{X}$=2.10) and theft and pilfering was ranked eight ($\overline{X}$=2.05). This result agrees with the findings of Afolami *et al*, (2013) in his research on the analysis of profitability and constraint in poultry egg farming showed that feed cost, non-remunerative price for egg and birds and supply of poor quality feed and feed ingredients, high cost of medicines and vaccines, lack of disease control facilities and high rate of electricity tariff are some of the factors influencing profit in egg production. Also, Bongani and Micah (2013) stated in the research on the determinant of profitability of indigenous chicken that feed cost, market price, stock size, number of birds sold and number of birds consumed are some of the factors that determine the profitability of indigenous chicken. Others constraints such as inadequate water supply ($\overline{X}$=1.10), shortage in labour supply ($\overline{X}$=1.06), marketing problem ($\overline{X}$ =1.24) , high mortality rate ($\overline{X}$=1.27), lack of access to information ($\overline{X}$=1.48), inadequate veterinary services ($\overline{X}$=1.83), poor weather conditions ($\overline{X}$ =1.47), scarcity of feed ingredients ($\overline{X}$=1.62), improper bio-security measures ($\overline{X}$=1.15) among others with mean less than 2.0 were not severe constraints faced in poultry production in the study area.

Test of hypothesis: Table 6 shows Correlation between some related socio economic characteristics and competence level of staff in poultry production. The table shows that all the variables tested in the hypothesis except age were significant. Level of education of staff is significantly correlated with the competence level of poultry staff at 1%, which implies that education positively have effect on competency. This implies that the higher the level of education the higher the competency of the poultry staff. This may be because educated staff can have access to much information and better informed. This is in line with the findings of Nadia (2013) who regarded education as a potential for cultivating the orientation of employees, the promotion of capabilities for future work, and a series of arrangement and learning. Experience of staff and membership of poultry association also has a corresponding positive influence on the competence level of poultry staff at 5% levels. This may be because staffs that belong to association can gain from other poultry farmers through sharing.

Table 2: Distribution of respondents by socio-economic characteristics (n = 120)

Variables	Frequency	Percentage
Age		
26-30yrs	25	20.83
31-35yrs	45	37.5
36-40yrs	33	27.5
41-50yrs	17	14.17
Total	120	100
Gender		
Male	109	90.83
Female	11	9.17
Total	120	100
Marital Status		
Single	22	18.33
Married	95	79.17
Widow(er)	3	2.5
Total	120	100
Education Status		
Secondary education	5	4.17
First Degree	109	90.83
Post graduate	6	5
Total	120	100
Years of Experience		
1-5yrs	98	81.67
6-10yrs	20	16.67
>10yrs	2	1.66
Total	120	100
Poultry Association Membership		
Yes	37	30.83
No	83	69.17
Total	120	100
Monthly Salary (₦)		
30000-39000	52	43.33
40000-49000	33	27.5
50000-59000	19	15.83
60000-69000	8	6.67
70000-79000	2	1.67
80000-89000	2	1.67
90000-99000	3	2.5
>100000	1	0.83
Total	120	100

Source: Data Analysis, 2016

Table 3: Distribution of respondents by entrepreneurial activities engaged in

Entrepreneurial activities	Low	Moderate	High	Mean	Rank
Ability to account for all the units of the poultry farm	2 (1.67)	16(13.33)	102(85.00)	3.37	1st
Ability to mobilize and maximize resources and skills for the farm	2(1.67)	8(6.67)	112(93.33)	2.95	2nd
Ability to keep viable farm records	0 (0)	10(8.33)	110(91.67)	2.92	3rd

Good communication and inter personal relationship with the customers	0(0)	12(10.00)	98(90.00)	2.9	4th
Ability to prepare farm budgets	0(0)	14(11.67)	106(88.33)	2.88	5th
Ability to prepare farm financial statements	0(0)	15(12.50)	105(87.50)	2.88	5th
Ability to correctly identify and correct production problems	4(3.33)	10(8.33)	106(88.33)	2.88	5th
Ability to use inputs with minimum cost to get maximum efficiency	2(1.67)	14(11.67)	104(86.66)	2.85	8th
Ability to predict and estimate the income from production over a period of time	4(3.33)	13(10.83)	103(85.33)	2.83	9th
Ability to design production programs and identify production targets	3(2.50)	17(14.17)	100(83.33)	2.81	10th
Ability to identify training needs	12(10.00)	15(12.50)	90(75.00)	2.6	11th
Ability to get and use credit and financial resources from various sources	2(1.67)	56(46.67)	62(51.66)	2.5	12th
Ability to advertise and create markets for farm produce	10(8.33)	48(40.00)	62(51.67)	2.43	13th
Ability to use best management operations in poultry production units	9(7.50)	51(42.5)	60(50.00)	2.43	13th
Ability in marketing agricultural produce	10(8.33)	50(41.67)	60(50.00)	2.42	15th
Ability to maintain a stable price control	15(12.50)	60(50.00)	45(37.50)	2.25	16th
Ability to make good decision about the technologies to accept and use	6(5.00)	84(70.00)	30(25.00)	2.2	17th
Ability to set goals and targets for the farm	5(4.17)	99(82.50)	16(13.33)	2.09	18th
Ability to organize seminars and training for staff at different unit of poultry farm	57(47.50)	50(41.67)	13(10.83)	1.63	19th
Ability to source for and get innovation ideas for maximum production	5(4.17)	98(81.67)	17(14.17)	0.73	20th

Source: Data Analysis, 2016

Table 4: Distribution of respondents on technical competence in poultry production

Variables	Highly skilled	Skilled	Moderately skilled	Not skilled	Mean	Rank
Disease diagnosis	105(87.50)	10(8.33)	5(4.17)	0(0.00)	3.83	1st
Identifying percentage of feed ingredients	105(87.50)	9(7.50)	6(5.00)	0(0.00)	3.83	1st
Feed formulation	101(84.17)	13(10.83)	6(5.00)	0(0.00)	3.79	3rd
Writing of monthly reports	74(61.67)	31(25.83)	13(10.83)	2(1.67)	3.48	4th
Use of improved breeding stocks	22(18.33)	78(65.00)	17(14.17)	3(2.50)	2.99	5th
Vaccination	15(12.50)	87(72.50)	18(15.00)	0(0.00)	2.98	6th
Record keeping	15(12.50)	87(72.50)	16(13.33)	2(1.67)	2.96	7th
Bio-security measures against diseases outbreak	11(9.17)	95(79.17)	12(10.00)	2(1.67)	2.96	7th
Mortality management	7(5.83)	100(83.33)	10(8.33)	3(2.50)	2.93	9th
Use of drugs	4(3.33)	98(81.67)	18(15.00)	0(0.00)	2.88	10th
Debeaking	12(10.00)	85(70.83)	19(15.83)	4(3.33)	2.88	10th
Culling	11(9.17)	90(75.00)	12(10.00)	7(5.83)	2.88	10th
Fumigation	6(5.00)	94(78.33)	20(16.67)	0(0.00)	2.88	10th
Use of disinfectants	6(5.00)	92(76.67)	22(18.33)	0(0.00)	2.87	14th
Brooding Operation	10(8.33)	86(71.66	20(16.66)	4(3.33)	2.85	15th
Litter management	18(15.00)	65(54.17)	35(29.17)	2(1.67)	2.83	16th
Egg collection and packing	5(4.17)	88(73.33)	25(20.83)	2(1.67)	2.8	17th
Gutter management	10(8.33)	40(33.33)	65(54.17)	5(4.17)	2.46	18th
Weighing of feed	9(7.50)	17(14.17)	91(75.83)	3(2.50)	2.27	19th
Sanitation of farm environments	6(5.00)	4(3.33)	90(75.00)	20(16.66)	1.82	20th

Source: Data Analysis, 2016

Table 5: Distribution of respondents by constraint faced in poultry production

Variables	Not severe	Severe	Very severe	Mean	Rank
High cost of vaccines and drugs	1(0.83)	25(20.83)	94(78.33)	2.78	1st
Inadequate capital	7(5.83)	31(25.83)	82(68.33)	2.63	2nd
Untimely availability of good day-old chicks	8(6.67)	37(30.83)	75(62.50)	2.56	3rd
High cost of feed	20(16.67)	28(23.33)	73(60.83)	2.46	4th
Financial problem	2(1.17)	77(64.17)	41(34.17)	2.33	5th
Pest and diseases attack	8(6.67)	77(64.17)	35(29.17)	2.23	6th
Lack of access to credit facilities	0(0.00)	108(90.00)	12(10.00)	2.10	7th
Theft and pilfering	3(2.50)	108(90.00)	9(7.50)	2.05	8th
Inadequate veterinary services	50(41.67)	42(35.00)	28(23.33)	1.82	9th
Scarcity of feed ingredients	50(41.67)	66(55.00)	4(3.33)	1.62	10th
Lack of access to information	65(54.17)	52(43.33)	3(2.50)	1.48	11th
Poor weather conditions	68(56.67)	48(40.00)	4(3.33)	1.47	12th
High mortality rate	90(75.00)	28(23.33)	2(1.17)	1.27	13th
Hatchery problem	94(78.33)	20(16.67)	6(5.00)	1.27	13th
Marketing problem	98(81.67)	15(12.50)	7(5.83)	1.24	15th
Inappropriate Bio-security measures	107(89.17)	8(6.67)	5(4.17)	1.15	16th
Packaging problem	108(90.00)	9(7.50)	3(2.50)	1.13	17th
Inadequate water supply	110(91.67)	8(6.67)	2(1.17)	1.10	18th
Transportation problem for staff and produce, to and from the farm	112(93.33)	6(5.00)	2(1.17)	1.08	19th
Shortage in labour supply	113(94.17)	7(5.83)	0(0.00)	1.06	20th

Source: Data Analysis, 2016

Table 6: Correlation between some selected socio economic characteristics and competence level of the respondents

Variables	**r -Value**	**P-Value**	**Decision**
Age	0.038	0.681	Not significant
Education	0.366	0.000	Significant
Experience	0.199	0.068	Significant
Poultry association	0.023		Significant

Source: Data Analysis, 2016 **correlation is significant at 0.01 level, *correlation is significant at 0.05 level

CONCLUSION AND RECOMMENDATIONS

The study concludes that in spite of high entrepreneurial activities and high competency observed in poultry staff, the major setback affecting poultry production in the study areas were untimely supply of good day old chick, inadequate capital, high cost of vaccines and drugs and high cost of feed. The study therefore recommends that more commercial hatcheries should be encouraged to spring up so as to increase the availability of more day old chicks. Poultry farmers should be encouraged to form cooperatives where information can easily be disseminated. Vaccines and drugs for poultry and other veterinary use should be subsidized by government while local production of such drugs and vaccines should be encouraged at affordable price. Finally, capacity training and seminars for poultry farmers and staff should be done so as to enable them cope with the challenges of modern poultry farming

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PERFORMANCE AND NUTRIENT UTILIZATION OF WEANER RABBITS FED BOILED SORREL SEED (*HIBISCUS SABDARIFFA* L) BASED DIETS

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ABSTRACT
An experiment was conducted to evaluate the effect of boiled sorrel seed meal (BSSM) diets on growth performance and nutrient digestibility of weaner rabbits. Thirty weaner rabbits of mixed breeds and both sexes with an average weight of 800 ± 76.0g (mean ± SD) were used for the experiment which lasted for 8 weeks. The rabbits were randomly allotted to five (5) dietary treatments containing the control diet, raw seed diet (BSS0) and boiled sorrel seeds in already boiled water per batch for 15 (BSS15), 30 (BSS30) and 45 (BSS45) minutes, respectively. Completely randomized design (CRD) was used with six (6) rabbits per treatment and two (2) rabbits per replicate. The results of the experiment showed that there was significant difference (P<0.05) in average daily feed intake but none (P>0.05) in other performance indices evaluated. Feed conversion ratio was better in rabbits fed BSS30 (6.28) compared to rabbits fed BSS45 (7.69). The final weight increased as boiling duration increased but later declined at 45 minutes duration (1360.00, 1286.67, 1293.33, 1386.67 and 1306.00g/rabbit). All parameters studied for nutrient digestibility were significantly affected (P<0.05) by duration of BSSM except for dry matter (DM) and ash. This indicated that the feed was better utilized and also had better nutrient digestibility. Based on the results of the study, it was therefore concluded that grower rabbits could tolerate sorrel seed meals up to 30 minutes duration of boiling without negatively affecting performance (daily feed intake) and poor nutrient digestibility (CP, CF, EE and NFE). Boiling beyond 30 minutes can lead to poor performance and utilization of the nutrients due to reduced B-carotene in the seeds. Given the economic potential of sorrel seed as a non-conventional feedstuff, histopathological studies are recommended to investigate any deleterious effects on rabbits fed sorrel seed-based diets.

KEYWORDS: Sorrel seed (*Hibiscus sabdariffa L.*), performance, nutrient digestibility, rabbits

INTRODUCTION
Rabbits have been recognized to have a very important role to play in the supply of animal protein to Nigerians, especially, in the rural and some part of urban areas. They are good converters of feed to meat and can utilize up to 30% crude fibre as against 10% by most poultry species. (Egbo *et al.,* 2001). Rabbits recently have come under focus as they are animals with several potentials such as short gestation periods, small body sizes, highly prolific, fast growth rate, and forage utilizers. Rabbit meat as an economic source of high-quality animal protein in the nutrition of human populations in the most of the tropical regions is gradually expanding (Amadi *et al.,* 2016). In recent years, it is economically nonviable and practically unsustainable for agricultural industry to solely depend on conventional feed (Merino *et al*., 2010). Limited supply, increasing demand and high price of conventional feed ingredients have been the motivating factors to explore alternative sources for livestock feed production (Odetola and Eruvbetine, 2012). The use of cheap, non-conventional feedstuff such as sorrel seeds maximize its potential as a feedstuff and further reduce the cost of producing animal protein while ensuring a continual development of the industry (Maikano *et al*., 2014). Sorrel seeds in their raw state are known to have bitter taste which is attributed to anti-nutritional factors present in them. The unprocessed seed have been reported to contain total phenols, phytic acid as common anti-nutrients and these have been shown to have detrimental effects on the health and performance of animals (Dairo *et al.,* 2011; Keyembe, 2011; Kwari *et al.*, 2011) and tannin; the major anti-nutrient which is known to impair feed intake, nutrient digestibility and growth of poultry and young animals. The seed also contain traces of saponin which reduces palatability and this can be reduced by repeated washing in water according to Nityanand (1997). Boiling as a processing method appears to be a more effective method of tannin reduction in sorrel seed than roasting or soaking in water. Boiling decreases tannin in sorrel seed to about 68% (Duwa *et al.,* 2012). Sorrel seeds contain high amount of protein, dietary fibre, and mineral such as phosphorus (P), calcium (Ca) and magnesium (Mg) (Ismail *et al*., 2008). The seeds contain about 35.90% crude protein (CP), 10.14% ether extract (EE), 10.09% ash and 15-17% crude fibre (CF) (Dashak and Nwanegbo, 2002). Kwari *et al.* (2011) also reported raw sorrel seeds to contain 5.18% arginine, 16.5% CF, 13.5% EE and 38.57% CP. Abdu *et al*. (2008) reported 23.46% CP value in the raw seeds. However, Nyameh *et al.* (2012) reported that boiled sorrel seeds contain 22. 84% CP, 8.50% CF, 6.50% EE, 6.50% ash, 45.66% NFE and 91.70% DM. while Maikano *et al.* (2014) reported a

value of 21.84% CP, 3.60% CF, 5.85% EE, 5.39% ash, 90.40% DM, 53.72% NFE, 1.12% Ca and 0.56% P. There is still paucity of information on the effect of utilizing non-conventional feedstuff in rabbit's diet. The experiment was therefore designed to investigate the performance and nutrient digestibility of feeding weaner rabbits with boiled sorrel seed meal-based diet.

METHODOLOGY

The Study area: The experiment was carried out at the Rabbitry Unit of the Department of Animal Science Teaching and Research Farm, Ahmadu Bello University, Zaria. Zaria is within the Northern Guinea Savanna zone of Nigeria, with Latitude 11º 09′ 01.78″N and Longitude 7º 39′ 14.79″E at an altitude of 671m above sea level (Ovimaps, 2015).

Experimental diets and proximate analysis:
Sorrel seeds and other ingredients used were purchased from an open market in Sabon Gari, Zaria. Fifteen kilogrammes (15kg) of raw sorrel seeds were thoroughly cleansed and milled to be incorporated into the diets of rabbits. Another 15kg of the seeds were cleansed and poured into 30litres of already boiled water at 100^0C per batch for 15, 30 and 45 minutes, respectively. The boiled seeds were later sundried for 3 days and milled into powder using hammer mill. It was bagged and stored for experimental diet formulation purpose.
Five (5) experimental diets (Table 1) were formulated to meet the requirements of rabbits according to National Research Council (1994). Treatment 1: Control diet (sorrel seed free diet); Treatment 2: Raw sorrel seeds diet (BSS0); Treatment 3: Diet containing sorrel seeds boiled for 15 minutes (BSS15); Treatment 4: Diet containing sorrel seeds boiled for 30 minutes (BSS30); and Treatment 5: Diet containing sorrel seeds boiled for 45 minutes (BSS45). The experimental diets were analysed for dry matter, ash, crude fibre, crude protein, ether extract, nitrogen free extract and metabolizable energy according to the methods of AOAC (2005).

Experimental design and management of animals: Thirty (30) weaner rabbits of mixed breeds and both sexes aged 7-8 weeks with an initial weight range of between 800 ± 76.0g (mean ± SD) were randomly allotted into five (5) groups of 6 animals after balancing for body weight. Each dietary treatment was replicated thrice (two animals per replicate) in a Completely Randomized Design (CRD). Before the commencement of the experiment, the rabbits were observed carefully for any ill-health and treated against ectoparasites and endoparasites using ivermectin® (0.25mg/kg/rabbit) The rabbits were housed individually in galvanized wire cages of 40 x 60 x 60cm dimension which were designed for easy collection of faeces. Each cage was equipped with a small rubber bowl drinker and an earthen pot feeder. The rabbits were fed *ad-libitum* and necessary routine management practices were duly followed. The experiment lasted for 56 days.

Data collection: Feed offered and left over were weighed to determine feed intake of the animals. After the initial weight, weekly weights were recorded, and the records were used to monitor and determine the performance parameters in terms of average feed intake (AFI), average weight gain (AWG), feed conversion ratio (FCR), final body weight and feed cost/kg gain. Mortality was also recorded as it occurred.

Digestibility study: A seven-day faeces collection from three rabbits per treatment (one per replicate) was carried out to determine the nutrient digestibility of the proximate components. Before the commencement of the digestibility trial, rabbits were weighed, confined individually in metabolism cages. Fresh, clean water and weighed quantity of feed was offered to each rabbit daily. Daily feed consumption was recorded as the difference between the quantity offered and the quantity left after 24 hours. A polythene sheet was placed under each cage to allow for individual faecal collection. The faeces were oven-dried to determine moisture content. At the end of the collection period, all faecal samples from each rabbit were bulked and preserved for proximate analysis according to A.O.A.C. (2005). The nutrient digestibility was calculated using the formula below

$$\text{Apparent Digestibility} = \frac{\text{Nutrient in feed intake} - \text{Nutrient in feacal output}}{\text{Nutrient in feed intake}} \times 100$$

Analysis: All data generated were subjected to Analysis of Variance (ANOVA) using General Linear Model (GLM) Procedure of SAS (2008) software package. Significant difference between treatment means were separated using Dunnett (Steel and Torrie, 1998).

RESULTS AND DISCUSSION

As shown in Table 2, the indices measured for growth performance showed no significant differences ($P>0.05$) except for total and average daily feed intake which were reduced significantly ($P<0.05$) as the duration of boiling increased. Rabbits fed control, BSS0 and BSS15 diets were statistically the same as compared to rabbits on BSS30 and BSS45 diets in terms of daily feed intake. It was observed that rabbits fed the BSS30 diet had the lowest average daily feed intake, highest weight gain, the least FCR and feed cost /kg weight

gain. This can be an indication that the rabbits were able to utilize and convert feed to gain. Similar results were reported by Kaga, (2013) when *Delonix regina* seeds cooked at different duration were fed to rabbits. Mortality of 0.33% was only recorded for rabbits on BSS45 diet. The FCR of rabbits fed BSS30 diet was the best although there were non-significant (P>0.05) differences when compared with control, BSS0, BSS15 and BSS45 diets. This agreed with the reports of (Musa and Ogbadoyi, 2012) who stated that boiling reduces the level of anti-nutrients and toxic substances with retention of most micro-nutrients in amount sufficient to meet animal's dietary requirement but boiling beyond BSS30 reduces B-carotene levels in seeds. Despite the anti-nutrients present in the BSS0 diet, they performed better than rabbits on BSS45 diet. This is because prolonged boiling reduces the B-carotene level in leguminous seeds and also leaching and denaturation of protein in the samples. This agrees with the findings of Kwari *et al.* (2011) who reported similar outcome when they fed raw, soaked, sprouted and boiled roselle seed meal to broiler chickens for 9 weeks. This could be as a result of better feed utilization by the rabbits on BSS0 diet. The result also supported the findings of Halimatul *et al.* (2007) who reported that the quality of two differently processed (dried and boiled) roselle seed powder are similar and affect performance significantly when the seeds were boiled at 100^{o} C for 30 minutes. Therefore, the anti-nutrient of raw sorrel seed might not affect feed digestibility and biological value.

Nutrient digestibility parameters studied (Table 3) were significantly affected (P<0.05) by duration of BSSM except for dry matter (DM) and ash digestibilities. Rabbits fed the control and BSS30 diets showed the best result for ether extract (EE) digestibility but declined significantly (P<0.05) with increased level of boiling (BSS45) thus, rabbits fed this diet showed the poorest result. Crude protein (CP) digestibility increased as the duration of boiling increases but declined significantly (P<0.05) at BSS45 diet. Crude protein digestibility of rabbits on BSS0, BSS15 and BSS30 diets were similar and better than digestibility on control and BSS45 diets. Crude fibre (CF) digestibility was significantly affected (P<0.05) by duration of boiling as rabbits fed BSS0 and BSS30 diets had statistically the same and best result. Similarly, no difference was observed for rabbits fed control and BSS15 diets. The least value (72.32) for CF digestibility was observed for rabbits fed BSS45 diet. The best result (67.11) for NFE digestibility was obtained in rabbits on BSS15 diet. The least result (54.11) was obtained from rabbits fed the control diet.

Crude fibre digestibility and ether extract digestibility values seem to be higher in all treatment than its relative values in crude protein and NFE. This indicates that the diets contain high fibre and fat. The results obtained in this study contradict the findings of Oso *et al.* (2011) who observed decreased nutrient digestibility with increased fermented sorrel seed meal. It was also not similar with the result of Saidu, (2015) who reported a general trend of digestibility result indicating reduced nutrient digestibility with increased level of autoclaved castor seed meal. It was observed that rabbits on BSS30 diet had higher EE digestibility result while the lowest was observed in rabbits on BSS45 diet. This is similar with the result of Kaga, (2013) who reported that diets with high fat contents are better digested by animals and have better nutrient digestibility. The reduced nutrient digestibility noticed in rabbits on BSS45 diet may be as a result of dilution effect of fibre. Apart from this complex toxic effect, sorrel seeds contain relatively high amount of fibre that reduced utilization of other nutrients in the body of the rabbits when cooking duration is prolonged. This supported the reports of (Longe and Ogedenge, 1989., Attah and Nyachoti, 2017) which stated that diluting diet with fibre source contributed immensely to the bulkiness of the resultant diets hence reducing nutrient digestibilities.

Table 1: Composition of experimental diets

	Duration of boiling of sorrel seeds (mins)				
Ingredients (kg)	**Control**	**BSS0**	**BSS15**	**BSS30**	**BSS45**
Maize	45.05	36.98	38.09	38.12	38.33
Soya bean cake	12.45	5.52	4.41	4.38	4.17
Boiled sorrel seed meal	0.00	15.00	15.00	15.00	15.00
Groundnut Haulms	40.00	40.00	40.00	40.00	40.00
Bone meal	2.00	2.00	2.00	2.00	2.00
Salt	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Proximate composition of diets					
Dry Matter	89.63	90.76	90.48	90.41	90.27
Crude Protein	15.39	15.45	15.35	15.84	15.45

Crude Fibre	9.65	10.90	7.05	6.70	6.37
Ether Extract	15.45	14.90	14.50	14.40	14.00
Ash	10.36	10.04	9.44	9.00	8.71
Nitrogen Free Extract	49.15	48.71	53.66	54.06	55.47
Metabolizable Energy (kcal/kg)	3553.49	3495.32	3632.15	3656.10	3658.30

**Bio-premix supplied per kg of diet: Vit A, 12500 I.U; Vit D_3, 2500 I.U; Vit E, 50mg; Vit K_3, 2.5mg; Vit B_3, 3.5mg; Vit B_6, 6mg; Niacin, 40mg; Pantothenic acid, 10mg; Biotin, 0.8mg; Vit B_{12}, 0.25mg; Folic acid, 1mg; Choline chloride, 300mg; Manganese, 100mg; Iron, 50mg; Zinc, 45mg; Iodine, 1.55mg; Selenium, 0.1mg; Copper, 2mg; Cobalt, 20mg.
BSS0 = Raw sorrel seed based diet (0 minutes) BSS15= boiled sorrel seed based diet at 15 minutes BSS30= boiled sorrel seed based diet at 30 minutes BSS45= boiled sorrel seed based diet at 45 minutes

Table 2: Effect of different duration of boiled sorrel seed meal on performance of grower rabbits

	Duration of boiled sorrel seed (mins)						
Indices	Control	BBS0	BSS15	BSS30	BSS45	SEM	LOS
Initial body weight (g/rabbit)	853.33	800.00	813.33	876.67	855.00	48.83	NS
Final body weight (g/rabbit)	1360.00	1286.67	1293.33	1386.67	1306.00	85.91	NS
Average daily weight gain (g/rabbit)	9.05	8.69	8.57	9.11	8.07	0.90	NS
Total feed intake	3476.48^{a}	3517.36^{a}	3587.36^{a}	3178.56^{b}	3265.92^{b}	129.92	*
Average daily feed intake (g/rabbit)	62.08^{a}	62.81^{a}	64.06^{a}	56.76^{b}	58.32^{b}	2.32	*
Feed conversion ratio	6.87	7.28	7.61	6.28	7.69	0.73	NS
Feed cost per kg (₦)	100.21	95.41	95.55	95.56	95.58		
Feed cost/kg gain	688.17	694.84	727.28	600.20	735.82	69.61	NS
Mortality (%)	0.00	0.00	0.00	0.00	0.33	0.15	NS

BSS0 = Raw sorrel seed based diet (0 minutes) BSS15= boiled sorrel seed based diet at 15 minutes BSS30= boiled sorrel seed based diet at 30 minutes BSS45= boiled sorrel seed based diet at 45 minutes
abc: means with different superscript on the same row differ significantly at $p<0.05$
SEM: standard error of mean LOS : level of significance NS : Not significant NS : Not analysed

Table 3 : Effect of different duration of boiled sorrel seed meal on nutrient digestibility

	Duration of Boiled Sorrel Seeds (mins)						
Parameters (%)	Control	BSS0	BSS15	BSS30	BSS45	SEM	LOS
Dry Matter	71.92	73.81	76.12	71.78	71.82	1.66	NS
Crude Protein	65.08^{ab}	54.16^{b}	70.24^{ab}	75.97^{a}	50.56^{b}	5.27	*
Crude Fibre	75.06^{b}	78.09^{ab}	76.66^{b}	81.15^{a}	72.32^{c}	1.45	*
Ether Extract	79.83^{a}	75.63^{b}	75.44^{b}	81.54^{a}	66.42^{c}	2.02	*
Ash	79.09	80.83	80.27	82.65	80.34	1.38	NS
Nitrogen Free Extract	54.11^{b}	64.61^{a}	67.11^{a}	65.32^{a}	62.44^{ab}	2.16	*

BSS0 = Raw sorrel seed based diet (0 minutes) BSS15= boiled sorrel seed based diet at 15 minutes BSS30= boiled sorrel seed based diet at 30 minutes BSS45= boiled sorrel seed based diet at 45 minutes
abc: means with different superscript on the same row differ significantly at $P<0.05$
SEM : standard error of mean LOS : level of significance NS : Not significant

CONCLUSION AND RECOMMENDATION

Although rabbits could tolerate raw sorrel seed in their diets without negatively affecting performance and nutrient digestibility, rabbits feed sorrel seed boiled for 30 minutes had superior nutrient digestibility. However, boiling duration beyond 30 minutes resulted in a decline in their performance and led to poor utilization of the nutrients. Given the economic potential of sorrel seed as a non-conventional feedstuff, histopathological studies are recommended to investigate any deleterious effects on rabbits fed sorrel seed-based diets.

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PROXIMATE COMPOSITION AND SENSORY PROPERTIES OF COOKIES PREPARED FROM WHEAT AND SPROUTED SORGHUM FLOUR BLENDS

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ABSTRACT

The study was conducted to determine the proximate composition of raw and sprouted sorghum flour as well as the proximate and sensory properties of cookies prepared from wheat and sprouted sorghum flour blends. Sorghum flour was sprouted for 72 h and its proximate composition was evaluated while non-sprouted sorghum flour served as control. Wheat flour was substituted with different proportions of sprouted sorghum flour for the preparation of cookies where 100 % wheat cookie served as control. The proximate and sensory properties of cookie samples were evaluated using standard methods. Results obtained showed that sprouting increased the protein, fat and crude fiber content of sorghum flour while ash and carbohydrate content decreased. Substitution of wheat flour with increasing level of sprouted sorghum flour increased the protein, ash, crude fiber and fat contents of the prepared cookies while carbohydrate and energy values decreased compared to control. Acceptable cookie was prepared by substituting wheat flour with 20 % sprouted sorghum flour.

Key words: Sorghum, Sprouted, Wheat, Substitution.

INTRODUCTION

Cereals supply the bulk of the food eaten by the human race. They are the cheapest source of food energy and protein intake of man particularly in developing countries. Commonly cultivated cereals are wheat, rice, rye, oats, corn and sorghum. Sorghum is a cereal crop that is grown in semi-arid zones of Africa, Asia and South America because of its drought tolerance. It is the fifth most important world cereal, followed by wheat, maize, rice and barley (Zohary, 2000, Aremu et al., 2007). Sorghum contains some nutrients such as carbohydrate, protein, lipids, minerals and vitamins. However, they are made unavailable for use by the body because of the presence of some anti-nutritional factors such as phytic acid and polyphenols (Chavan & Kadan, 1993).

Germination processes have been developed to overcome these disadvantages of sorghum in food products (Zohary, 2000). Germination which also means sprouting is a complex metabolic process during which lipids, carbohydrate and storage proteins

Within the seeds are broken down to obtain the energy and amino acid necessary for the plant's development (Malomo *et al*., 2013). Germination or sprouting is a common problem for grain during harvest when the weather is moist or when the environment is humid during storage. Germination promotes the development of cytolytic, proteolytic and amylolytic enzymes that are not active in dry kennels (Akpapannan and Derbe, 1994, Ashcroft, 1973, FAO, 1996) and could cause significant changes in kernel composition and physical properties (Zohary, 2000).

Cookies are snacks that are widely recognized and eaten globally by people of all ages (Giwa and Ikujenlola (2010). In Nigeria cookies are one of the most consumed snacks apart from bread, because they are energy giving foods made traditionally and readily available in shops as ready to eat, convenient and inexpensive food products containing digestive and dietary principles of vital importance (Kulkarni, 1997). Cookies are produced as nutritive snacks from unpalatable dough that is transformed into appetizing products through the application of heat in the oven (Olaoye *et al.*, 2007). They are made from soft wheat flour but can also be produced with substitute grain flour with better nutritional quality which may be desirable particularly in the developing world where household malnutrition is common. Such grains may be processed using methods like sprouting / fermentations which have been reported to increase nutritional quality (Hallen et al ,2004). It is therefore expected that processing of sprouted sorghum flour in cookies production may greatly improve its nutritive value. Therefore, the objectives of the study were to determine the proximate composition of raw and sprouted sorghum flour. In addition, the proximate and sensory properties of cookies prepared from sprouted sorghum were analyzed.

METHODOLOGY

Materials: Sorghum grains, wheat flour, baking materials such as sugar, fat, egg, common salt and sodium bicarbonate or baking powder used in this study were purchased from Samaru Market, Zaria Kaduna State, Nigeria.

Preparation of raw and sprouted sorghum flour: The method of Houssou and Ayemor (2002) was used in the preparation of sprouted and non-sprouted sorghum flour. Sorghum grains were sorted to remove stones and unwanted materials. The cleaned sorghum grains were soaked in water for 24 hours; the sprouting grains were changed with clean water every 12 hours to prevent fermentation. The sprouted and non-sprouted sorghum grains were separately dried under room temperature for about 72 hours, milled into flour and sieved through 100 µm sieve size. The flour samples were packaged in plastic bag until used.

Formulation of blends: The composite flour was prepared by replacing sprouted sorghum flour (SSF) with wheat flour (WF) at 20%, 40%, 60%, 80% and 100%, and were labelled as T1, T2, T3, T4 and T5 respectively. Sample T0 with 100% SSF served as a reference sample.

Preparation of Cookies: Cookies were prepared using the method reported by Abayomi *et al*. (2013) and Olapade and Ogunade (2014), with little modification. Cookies dough prepared from wheat flour and composite flours combinations using flour (250g), margarine 100g, sugar100g, salt a pinch, sodium bicarbonate 10g, egg 150g. Sugar was creamed with margarine until a light and fluffy constituency was obtained; beaten egg was added, followed by flour, baking powder, and salt were added and mixed until a stiff paste (batter) was obtained. The batter was rolled on a food board using rolling pin to a thickness of 0.1–0.2 cm. The rolled batter was cut into desired shapes with a cutter and arranged on a greased tray and baked at 150°C for 30 min to golden brown. The cookies were brought out, cooled, and packaged in plastic bag until used for analysis.

Determination of proximate compositions of flour and cookies: Moisture, protein, fat, crude fiber and ash contents of samples were determined according to the method described in Association of Official Analytical Chemists (AOAC, 2005, AOAC,2000). The total carbohydrate (CHO) was calculated by difference as: CHO = 100-% moisture + % protein + % fat + %ash). Energy value (kcal/100 g) was determined according to the method of Marero *et al*. (1998) using Atwater factor method: 4 × % protein + 4 × % carbohydrate) + 9 × % fat.

Sensory evaluation of cookies: Sensory evaluation was carried out according to the method described by Retapol and Hooker (2006). A twenty- member panelists were selected based on their familiarity and experience with wheat-based cookies for sensory evaluation. Cookies produced from each flour blend, along with the reference sample were presented in coded form on white plastic plates and were randomly presented to each member. The panelists were provided with portable water to rinse their mouth between evaluations. Sensory attributes (colour, taste, flavour, crispiness and overall acceptability) of the cookies were evaluated on a 7-point Hedonic scale (1 = dislike extremely and 7 = like extremely).

Data Analysis: Data (triplicate values) obtained were analyzed using the Statistical Package for Social Sciences (SPSS version 20).

RESULTS AND DISCUSSION

Table 1 shows the proximate composition of raw and sprouted sorghum flour. Proximate composition of a grain gives a profile of nutrient constituents. Moisture, ash, protein, fat, crude fiber, carbohydrate and total energy of raw sorghum flours were 7.46%, 1.55%, 9.28%, 2.27%, 2.34%, 85.20%, 376.9%, respectively, while sprouted sorghum flour contained 7.54 % moisture, 1.33 % ash, 11.63 % protein, ,2.33 % fat, 4.84 % crude fiber, 81.91 % carbohydrate and 372.4 Kcal/100g energy value. The moisture content of sprouted sorghum was higher compare to raw sorghum flour. These results agree with the report of Mir *et al*. (2015) for sprouted wheat /wheat flour biscuit. The values of moisture (7.6–10.7%) and protein (9.6–13.5%) contents agreed with those reported by Onabanjo and Ighere (2014). The fibre content of sprouted sorghum flour sample (4.84) had the highest value while raw sorghum had the lowest value (2.34). The values of fibre contents of raw and sprouted sorghum agreed with the finding of Onabanjo and Ighere (2014). Sprouted sorghum flour has relatively higher crude fibre content than wheat flour. Higher crude fiber content of sprouted sorghum than raw flour could be attributed the formation of sprouts. The presence of high fibre in food products is essential owing to its ability to facilitate bowel movement (peristalsis), bulk addition to food and prevention of many gastrointestinal diseases in man (Satinder *et al*., 2011; Omeire and Ohambele, 2010). The fat content of sprouted sorghum flour was lower compared to that of raw sorghum probably because the sprouted grains utilized lipid as source of energy during sprouting. Carbohydrate content of the sprouted sorghum (81.91 %) was lower compared to raw sorghum flour (85.20%). This may be attributed to starch hydrolysis during sprouting process. Sprouted sorghum flour had the lowest energy value (372. 4%) while the raw sorghum sample had the highest value (376.9%). Similar trend in the carbohydrate and energy contents of sprouted sorghum flour made from wheat-brewers spent grain flour blends and whole wheat- full fat soya flour blends were previously reported by Nagaraj *et al*. (2013).

The results of proximate composition of cookies from sorghum flour and wheat flour at different blends are shown in Table 2. The moisture content (%) of the cookies ranged between 3.34 and 4.06 %. Cookie sample (T4) had the highest value. However, increased substitution level with WF caused significant ($p < 0.05$) reduction in the moisture content values. The moisture content of the cookies was low (<10%) to reduce the chances of spoilage by micro-organisms and consequently guarantee good storage stability (Ayo *et al*., 2007). The moisture content of the cookie samples decreased with increasing level of WF substitution. Gernah *et al*, (2010) reported higher moisture content (5.20–9.30%) for cookies made from sorghum grain flour blends. Ash content of the cookies ranged from 1.88 to 1.41%. The addition of sorghum flour significantly ($p < 0.05$) increased the ash content of the cookies. Ash content of a food material is an indication of the mineral constituents' present (Adebowale, Olayiwola, & Maziya-Dixon, 2008). It aids the metabolism of other compounds such as fat, protein and carbohydrate (Okaka and Ene, 2005, Omeire and Ohambele 2010, Giwa and Abiodun, 2010). Cookie sample (T1) had the highest protein content (15.64%) while (T5) had the lowest (11.21%). Increase SSF substitution caused significant ($p < 0.05$) increase in the protein content of the cookies. The findings conform with previous reports (Giwa and Ikujenlola (2010, Giwa & Abiodun., 2010, Ayo, Mkama and Adeworie, 2006; Adebowale *et al*.,2012) that observed significant increase in the protein content of sorghum-based cookies.

The fat content of the cookies ranged between 29.86 and 32.36%. Cookie sample (T5) had the highest fat content (29.86%) while (T1) had the least value (32.36%). The fat content of the cookies increased significantly ($p < 0.05$) as the substitution level increased. The finding agrees with Omeire and Ohambele (2010) and Gernah et al. (2010) on their reports for the increasing trend in the fat content of cookies produced from wheat-defatted cashew nut and wheat-brewers spent flour blends, respectively. The high fat content in the cookies means high calorific value and also improves the flavor and texture of the cookies (Giwa & Abiodun ,2010). The crude fibre content of the cookies ranged from 1.32 to 6.38%, with T1 having the highest crude fiber value while T4 had the lowest value. The increase in the crude fiber content of the cookies with increasing SSF level could be attributed to higher crude fiber content of SSF which caused addition effect in the blend. This result is in line with those of Gernah *et al*. (2010) for cookies prepared from wheat-brewers spent grain flour blends. The presence of high fibre in food products is essential owing to its ability to facilitate bowel movement (peristalsis), bulk addition to food and prevention of many gastrointestinal diseases in man (Satinder et al., 2011). Carbohydrate content of the cookies ranged between 40.05 and 52.79%. Sample (T1) had the lowest carbohydrate content (40.05%) while the sample (T5) had the highest value (52.79%). The increase in substitution proportion of wheat flour brought about decrease in the carbohydrate content of cookies. Similarly, a decreasing trend in the carbohydrate contents (73.46– 46.20%) and (70.45– 23.71%) of cookies made from wheat-brewers spent grain flour blends and whole wheat- full fat soya flour blends was reported by Gernah *et al* (2010).

The low carbohydrate content and increased fibre content of the composite cookies have several health benefits, as it aids digestion in the colon and reduces constipation often associated with products from refined grain flours (Elleuch et al., 2011). The energy value of the cookies ranged between 509.98 and 525.05 kcal/100 g; cookie sample (T2) had the lowest energy value, while the reference sample (T5) had the highest value. The energy values of the composite cookies were significantly at ($p < 0.05$). Similarly, a decreasing trend in the energy value (443.89–431.95 kcal) for cookies made from wheat and quality protein maize was reported by Giwa and Ikujenlola (2010).

Table 3 shows results of the sensory properties of cookies *p*repared from wheat and sprouted sorghum flour blends. The colour, taste, flavor, palatability and overall acceptability scores of the cookie samples were significantly different ($p < 0.05$) from one another. The control sample (T0) had the highest scores for all the attributes observed, except for colour and crispiness. The mean score for the cookies colour ranged between 7.1 and 8.4. Cookie sample (T1) had the lowest value while sample (T4) had the highest value. Generally, the scores for colour attribute increased with increasing SSF substitution level. The intense brown colour of the composite cookies could be due the presence of high amount of carbohydrate in the flour blends, thus resulting in caramelized product. In addition, this could be an indication that substitution of sorghum flour with wheat flour for cookie making actually provides more protein for Maillard reaction to take place, which is normally encountered and desirable in baked goods. Similar results were reported by other authors (Giwa and Abiodun, 2010; Akpapannan and Darbe, 1994). Texture and palatability scores of cookies increased with increasing level (up to 20 %) of SSF which later decreased.

Based on taste, the scores for the cookies ranged from 4.1 to 7.6; cookie sample (T4) had the lowest value while the reference sample (T0) and sample

(T1) had the same high value (7.6). The astringent taste observed among the cookie samples could be attributed to the development of bitter substances, owing to the presence of tannin in sorghum. From the result, it could be deduced that up to 20% substitution level wheat flour could be acceptable by consumers with a mean score of 7.6. The mean scores for flavor ranged between 4.3 and 8.3 for cookie sample (T4) and the reference sample (T0) respectively. However, there was a decrease in the aroma scores of the cookie samples with increase in the substitution level of WF. No significant differences ($p > 0.05$) exist between cookie samples; T2 and T3. The scores for the texture of cookies ranged from 5.0 to 8.2; cookie sample (T5) had the lowest value while sample (T1) had the highest value. The mean scores (5.4–8.8) for the overall acceptability of the cookies were above the average (4.5), indicating

The control sample (To) had the lowest overall acceptability score, while cookie sample (T5) had the highest value. The mean scores (5.5–7.8) for the overall palatability of the cookies were above the average (4.5), indicating high palatability of the cookie samples. The reference sample (T4) had the highest value, while cookie sample (T5) had the least value. The possible reason for low palatability of the cookie's samples produced with WF substitution level above 20% could be due to the observed dark brown coloration and bitter taste. It is therefore clear according to the result that substitution of wheat flours up to 100% substitution level could produce good quality cookies that are palatable, acceptable and suitable heath wise.

Table 1 Proximate composition of raw and sprouted sorghum flour

	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)	Total Energy (Kcal/100g)
Raw	7.46	1.55	9.28	2.27	2.34	85.20	376.9
Sprouted sample	7.54	1.33	11.63	2.33	4.84	81.91	372.4

Table 2: Proximate composition of cookies made from wheat and sprouted sorghum flour blends

	Moisture (%)	Ash (%)	Crude protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)	Energy value Kcal/100g
100% WF	3.34^{e}	1.41^{e}	11.21^{e}	29.86^{d}	1.32^{e}	52.79^{a}	525.02^{a}
20SSF:80WF	4.06^{a}	1.53^{d}	11.86^{d}	30.76^{c}	3.41^{d}	48.41^{b}	517.79^{b}
40SSF:60WF	3.78^{b}	1.62^{c}	13.17^{c}	30.76^{c}	4.24^{c}	46.43^{c}	515.24^{c}
60SSF:40WF	3.75^{c}	1.75^{b}	14.68^{b}	30.78^{b}	5.48^{b}	43.56^{d}	509.98^{e}
80SSF:20WF	3.65^{d}	1.88^{a}	15.63^{a}	32.36^{a}	6.38^{a}	40.05^{e}	514.00^{d}

Mean value with different superscript on the same column are significantly different ($p \leq 0.05$); SSF–Sprouted sorghum flour; WF– wheat flour; WF– wheat flour; To=100%SSF: 0%WF; T1= 80%SSF:20%WF; T2= 60% SSF:40% WF; T3=40% SSF–80% WF; T4–20% SSF–100% WF; T5- WF-100%WF; T4–20% SSF–100% WF; T5- WF-100%

Table 3: Sensory properties of cookies prepared from wheat and sprouted sorghum flour blends

Sample Sensory attributes of cookies

	Taste	Aroma	Colour	Texture	Palatability	Overall acceptability
100% WF	7.8^{a}	8.5^{a}	7.0^{e}	5.0^{f}	5.3^{f}	5.2^{f}
20SSF:80WF	7.6^{b}	8.3^{b}	7.3^{d}	7.7^{b}	7.8^{a}	8.8^{a}
40SSF:60WF	7.6^{b}	7.8^{c}	7.1^{e}	8.2^{a}	7.4^{b}	8.2^{b}
60SSF:40WF	7.1^{b}	6.5^{d}	7.5^{b}	5.3^{d}	7.0^{c}	7.3^{c}
80SSF:20WF	6.3^{c}	6.5^{d}	7.4^{c}	5.7^{c}	6.1^{d}	6.3^{d}
100SSF:0WF	4.1^{e}	4.3^{d}	8.4^{a}	5.2^{e}	5.5^{e}	5.4^{e}

Mean value with different superscript on the same column are significantly different ($p \leq 0.05$); SSF–Sprouted sorghum flour;

WF– wheat flour; WF– wheat flour; To=100%SSF: 0%WF; T1= 80%SSF:20%WF; T2= 60% SSF:40% WF; T3=40% SSF–80% WF; T4–20% SSF–100% WF; T5- WF-100%

WF; T4–20% SSF–100% WF; T5- WF-100%

CONCLUSION

Sprouting increased the protein, fat and crude fiber content of sorghum flour while ash and carbohydrate content decreased. On the other hand, substitution of wheat flour with sprouted sorghum flour increased the protein, ash, crude fiber and fat content of the prepared cookies compared to control. Acceptable cookie was prepared by substituting wheat flour with 20 % sprouted sorghum flour.

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EFFECT OF INOCULUM DENSITIES ON THE REPRODUCTIVE FITNESS AND PATHOGENICITY OF *PRATYLENCHUS COFFEAE* AND *MELOIDOGYNE INCOGNITA* ON*MUSA PARADISIACAL* L. IN PENINSULAR MALAYSIA

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ABSTRACT

Three weeks old tissue culture seedlings of Musa paradisiaca grown in pots containing autoclaved soil were inoculated with Pratylenchus coffeae and M. incognita inoculawith100, 250, 500 , 1000, 3000 and 5000 juveniles for each and mixture of the two nematodes at selected inoculum densities of 1000, 3000 and 5000 juveniles, and a negative control. Pathogen multiplications were observed after 12 weeks of growth. There were significant differences in vegetative growth($p \leq 0.05$) within the pathogens and among the various inoculum densities evaluated. Multiplication factors or Rf= population final/population initial ranged between 1.6-4 in P .coffeae and 0.6-7 in M. incognita. Reduction in root, shoot weights and lengths were significant ($p \leq 0.05$). Musa paradisiaca L. showed high level of susceptibility to the various inoculum densities evaluated. Despite the variation in reproductive factors between inoculum densities and among the nematodes examined, root lesion indices showed higher disease severity at all inoculum densities evaluated. At both minimum (100) and maximum (5000) inoculum densities studied, damage to the crop was severe.

Key words: *Meloidogyne incognita*, *Musa paradisiaca*, Pathogenicity, *Pratylenchus coffeae*, Reproductive fitness.

INTRODUCTION

Crop production has been threatened by nematode attack in the world; however, nematodes have not been stressed as crop pests of significance in Malaysia. Also, the damaging status of nematodes in agriculture has not received serious attention in the country. The reason for the lingering progress is not unrelated to the agricultural policies which lay preference on traditional perennial crops such as oil palm, cocoa and rubber which are seldom infected with nematodes (AbdulRahman *et al*, 2014). Damages to horticultural and agricultural plants by nematodes in Malaysia seem to be overwhelming and thus, require urgent attention (AbdulRahman *et al*, 2014).

Crops like banana (*Musa acuminata* Colla) [Razak, 1994; Razak and Loof, 1998; Hassan, 2004; AbdurRahman *et al*., 2014], guava (*Psidium guajava* L.) in Perak [Razak and Lim, 1987], chili (*Capsicum frustescens*), black pepper (*Piper nigrum* L.) and even grass (turf grass) on golf courses [Razak and Loof, 1998] have been affected. The available documented reports are mere field surveys, which point to the necessity of more investigations to establish the basics and attempt to discover solutions to this worm's problem.

In Malaysia, two species of migratory plant-parasitic nematodes are important on *Musa* spp., viz *Pratylenchus* spp. and *Meloidogyne* spp; as they have replaced *Radophulus simils*, a worldwide nematode of banana (AbdulRahman *et al*, 2014). About 76 species have so far been recorded in the genus *Pratylenchus* (De Waele and Elsen, 2007). Of these species only few are of agricultural importance and are responsible for significant crops damage and high yield losses. *Pratylenchus coffeae* (Zimmermann) Filipjev and Schuurmans Stekhoven, is one of the root-lesion nematodes that are of pathogenic importance to plants. Besides its wide host range, it also has a worldwide distribution (Castillo and Vovlas, 2007).

Pratylenchus spp. are often found in banana fields together with other nematodes species, like *Radopholus similis*, and the root-knot nematodes, which provide feeding site for their penetration. In nematology, the two main components of pathogenicity are virulence and reproductive fitness (Shaner *et al*., 1992), of which understanding and assessment of disease reactions of plants to pathogens are based. Pathogenicityis the ability of an organism to infect host plants and cause disease condition (Inomoto *et al*., 2007), while reproductive fitness is defined as the multiplication ability of a species or population on a specific host plant (Inomoto *et al.*, 2007).

The colonisation of more host tissue by *Pratylenchus* spp. and root-knot nematodes due to

their higher reproductive fitness makes it possible for them to cause severe damage on susceptible plants. Damages caused by nematodes to crops are often assessed on the basis of densities of the nematodes in the soil at planting and in the roots throughoutthe growing season. Thus, for economic decisions for nematodes management, damage threshold levels are effectively employed (Ferris, 1981). *Pratylenchus coffeae* and root-knot nematodes have been reported in banana fields in Malaysia since the early eighties, however, their damaging status hitherto are not yet defined.

Knowledge regarding the injury population level of *Pratylenchus* spp. and root-knot nematodeson *paradisiaca* in Malaysia is highly required. It is necessary to conduct a study on damaging levels and potentials of *Pratylenchus* spp alone or with other phytonematodes for management decisions. The aim of this investigation was, therefore, to determine the population at which damage on banana can occur due to *P. coffeae* infection alone or in combination with *M. incognita*.

METHODOLOGY

Glasshouse experimental layout: Tissue-culture plants of the cultivar *M. paradisiacal* were used as a source of nematode-free planting stock. This plant material was transferred to 2 kg plastic pots of 25 x 15cm dimension, filled with autoclaved soil in 3:2:1 sand, pit, clay. For each nematode species, mobile stages or mixture of juvenile and adult stages were inoculated i n three holes of 3 cm x 4 cm with 10 ml water at densities of 0, 100, 250, 500, 1000, 2000, 3000 and 5000, nematodes/cm^3 soil. After inoculation the holes were covered with soil. Each combination of nematode species-density was repeated five times. The pots were arranged in complete randomized design (CRD), consisting of 18 treatments viz: 0 negative control, 100 nematodes inoculum (ni), 250 ni, 500 ni, 1000 ni, 2000 ni, 3000 ni and 5000 ni, for each of *P. coffeae* and *M. incognita* and the mixture of the two nematodes at selected populations of 1000 ni, 3000 ni and 5000 ni. The potted plants were fertilized on monthly basis, with Peter's 20:20:20 general purpose N: P: K plant food at 0.25 g per litre of water. The plants were watered upon requirements and measurement done un-
destructively.

Assessment of plant vigour: At 2, 4, 6, 8, 10 and 12 weeks after inoculation (WAI) plant heights were measured every two weeks till the twelfth week. Measurement was conducted from the base of the seedling to the top part of the plant using a ruler tape. For leaf area, length and breadth of the selected leaves were also measured using rule tape. The circumference of the *pseudo stem* was taken using thread and ruler for the same period. At harvest or 12 WAI, shoot and root lengths were measured using measuring tape, while fresh shoot and root weight were measured with the aid of weighing balance SP (1-4 kg) by Zhongshan Camry Electronic Co. Ltd.China. The percent increase and reduction in the growth parameters over the control were calculated by using the formula:

% reduction =

$$\frac{(\text{Uninoculated} - \text{Inoculated})}{\text{Uninoculated}} \; x\,100$$

(Ansari *et al*., 2018)

Assessment of disease severity: Cortical root necrosis of *P. coffeae* and galling index of *M. incognita*, fresh root weight, shoot weight and final nematode densities (Pf) in both roots and soil were determined at 12 WAI.

For the root damage assessment, about 100 root pieces of 10 cm length were sliced lengthwise for scoring the diseases caused by lesion nematodes as described by Speijer and De Waele, (1997).

$$(\%) = \frac{\sum(N_1 x1)+(N_2 x2)+\cdots+(N_7 x7)}{\text{N x highest rating scale}} x100$$

where:
N1: The number of roots with necrosis at score 1
N3: The number of roots with necrosis at score 3
N5: The number of roots with necrosis at score 5
N7: The number of roots with necrosis at score7
N: Total number of roots evaluated

The damage of roots was grouped into five classes according to the percentage of root cortex covered by lesions as follows as described by (Speijer and De Waele, 1997):
Score 0: No lesions on the root cortex
Score 1: 1- 25% root cortex covered by lesions
Score 3: 26 - 50% root cortex covered by lesions
Score 5: 51 - 75% root cortex covered by lesions
Score 7: 76 - 100% root cortex covered by lesions

Root galling was assessed using 0-5 scale, according to Taylor and Sasser, (1978), where 0 = no galling, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls s and 5 = >100 galls.
For the roots, 2g of the galled portions were taken from each of the harvested banana plant and the galls counted, then multiplied by the weight of the root to give the approximate numbers of galls per plant.

Determination of reproductive factor (RF): At 12WAI, banana roots were carefully excised to remove the adhering soil from the root systems. Five roots with approximately equal length were taken and cut into segments, 10 cm from root tip and 10 cm in the middle with flamed scalpel between cuts to avoid transfer of inoculum from one segment to another.
Nematodes were recovered from 200cc soil subsamples and 10 g roots using whitehead tray method reported by Whitehead and Hemming

(1965). The final population (Pf)was obtained when one mL of the nematode suspension used in triplicates was each counted in a Huxley nematode counting slide through the use of the compound microscope. The averages of the triplicate counts represented nematodes in the pots by multiplying the average with the suspension from the 200 ml of soil and roots, and adding up the nematode numbers obtained from both soil and roots. The RF was determined from the relation:

RF=Pi/Pf (soil and roots).

Where RF= Reproductive Factor, Pi= initial nematode population and Pf= final nematode population.

Statistical Analysis: Data collected were subjected to one-way analysis of variance (ANOVA) using Statistical Analysis Software(SAS Institute, 2008). The differences among the means were separated using Waller-Duncan k ratio t test at P≤ 0.05

Assessment of plant vigour: The results of the pathogenicity trial on banana cultivar of *Musa paradisiaca* is presented in Tables 1-3. There was significant decrease in shoot height, shoot weight, fresh root length and weight of the banana by all the inoculum densities of the two nematodes, *Pratylenchus coffeae* and *Meloidogyne incognita*, either singly or in mixture as compared to control plants (Figs 1 and 2). There were significant differences among the treatments and the lowest root length reduction of 66.0 cm was recorded in P1 and the highest of 13.01 cm in P7 and the root weight followed the same trend. However, the shoot length and weight had significant reductionin P6 and P7 and the others were not significantly different from each other. Percentage reduction of the measured parameters as affected by *P. coffeae* ranged from-17.9 to -80. % root length, -21to 99.8% root weight, -14.7 to -45.8% for shoot length and -9.3 to -61.8% shoot weight compared to the control plants

RESULTS AND DISCUSSION

Table 1: Effects of different inoculum densities of *Pratylenchus coffeae* on fresh root and shoot lengths (cm) and weights (kg) of *Musaparadisiaca*at 12 weeks after inoculation

	Fresh roots and shoots lengths (cm) and weights (kg)							
Treatment	**Root length**	**% reduction**	**Root weight**	**% reduction**	**Shoot length**	**% reduction**	**Shoot weight**	**% reduction**
Control	86.48a		1.042a		102.34a		0.86a	
P1	66.0b	-23.7	0.82b	-21.3	88.92ab	-13.1	0.78ab	-9.3
P2	54.18bc	-37.3	0.098c	-90.6	88.1b	-13.9	0.61bc	-29.1
P3	39.24cd	-54.6	0.085c	-91.8	84.92b	-17	0.59bcd	-31.4
P4	33.54cde	-61.2	0.049c	-95.3	74.18c	-27.5	0.58bcd	-32.6
P5	28.02cde	-67.6	0.005d	-99.5	70.2cd	-31.4	0.42de	- 51. 2
P6	26.38de	-69.4	0.003d	-99.7	59.67de	-41.7	0.40e	-53.5
P7	13.01e	-84.9	0.0015e	99.9	55.46de	-45.8	0.33e	-61.6
MSD	26.11		0.18		13.51		0.19	

Means within columns that share the same letter (s) are non-significant at p = 0.05.

WAI=weeks after inoculation, Cont.=control treatment, P1= 100 nematode inoculum (ni), P2=250 ni, P3= 500 ni, P4=1000 ni, P5=2000 ni, P6=3000 ni, P7= 5000 ni.

Table 2: Effects of different inoculum densities of *Meloidogyne incognita* on fresh root and shoot lengths (cm) and weights (kg) of *Musaparadisiaca*at 12 weeks after inoculation

	Fresh Root and Shoot Lengnths (cm) and Weghts (Kg)							
Treatments	**Root L**	**% reduction**	**Root W**	**% reduction**	**Shootl**	**% reduction**	**Shootw**	**% reduction**
CONT	86.48a		1.04a		44.26a		0.86a	
P8	64.12b	-25.9	0.98b	-5.8	29.66b	-33	0.53b	-38.4
P9	61.21b	-29.2	0.82c	-21	26.82bcd	-39.4	0.52bc	-39.5
P10	58.72b	-32.1	0.80c	-23.1	23.4cde	-47.1	0.48bc	-44.1
P11	50.9bc	-30.7	0.76c	-26.9	21.94de	-50.4	0.45bc	-47.7
P12	47.08bc	-45.6	0.61d	-41.3	20.04ef	-54.8	0.43bc	-50
P13	44.38bc	-48.7	0.60d	-42.3	19.98ef	-54.9	0.42bc	-51.2
P14	37.72c	-56.4	0.52e	-50	15.24f	-65.6	0.32c	-62.8
MSD	21.3		0.06		6.61		0.21	

Means within columns that share the same letter (s) are non-significant at p = 0.05.

WAI=weeks after inoculation, Cont.=control treatment, P8= 100 nematode inoculum (ni), P9=250 ni, P10= 500 ni, P11=1000 ni, P12=2000 ni, P13=3000 ni, P14= 5000 ni.

RTLT=root length, RTWT=root weight, SHTLT=shoot length, SHTWT=shoot weight

Table 3: Effect of different mix nematodes inoculum densities (*Pratylenchus coffeae* and *Meloidogyne incognita*) on fresh root and shoot lengths (cm) and weights (kg) of *Musa paradisiacal* at 12 weeks after inoculation

	Fresh root and shoot lengths (cm) and weight (kg)							
Treatments	Root l	% reduction	Root wt	% reduction	Shoot l	% reduction	Shoot wt	% reduction
Contr	86.48a	0	1.04a	0	41.26a	0	0.87a	0
P15	7 5.54b	-12.7	0.10b	-90.4	29.88b	-27.6	0.65b	-25.3
P16	66.54c	-23.1	0.07b	-93.3	25.14bc	-39.1	0.46c	-47.1
P17	51.64d	-40.3	0.04c	-96.2	19.34b	-53.1	0.27d	-69
MSD	9.68		0.06		9.73		0.2	

Means within columns that share the same letter (s) are non-significant at p = 0.05.
WAI=weeks after inoculation, Cont.=control treatment, P8= 100 nematode inoculum (ni), P9=250 ni, P10= 500 ni, P11=1000 ni, P12=2000 ni, P13=3000 ni, P14= 5000 ni.
RTLT=root length, RTWT=root weight, SHTLT=shoot length, SHTWT=shoot weight

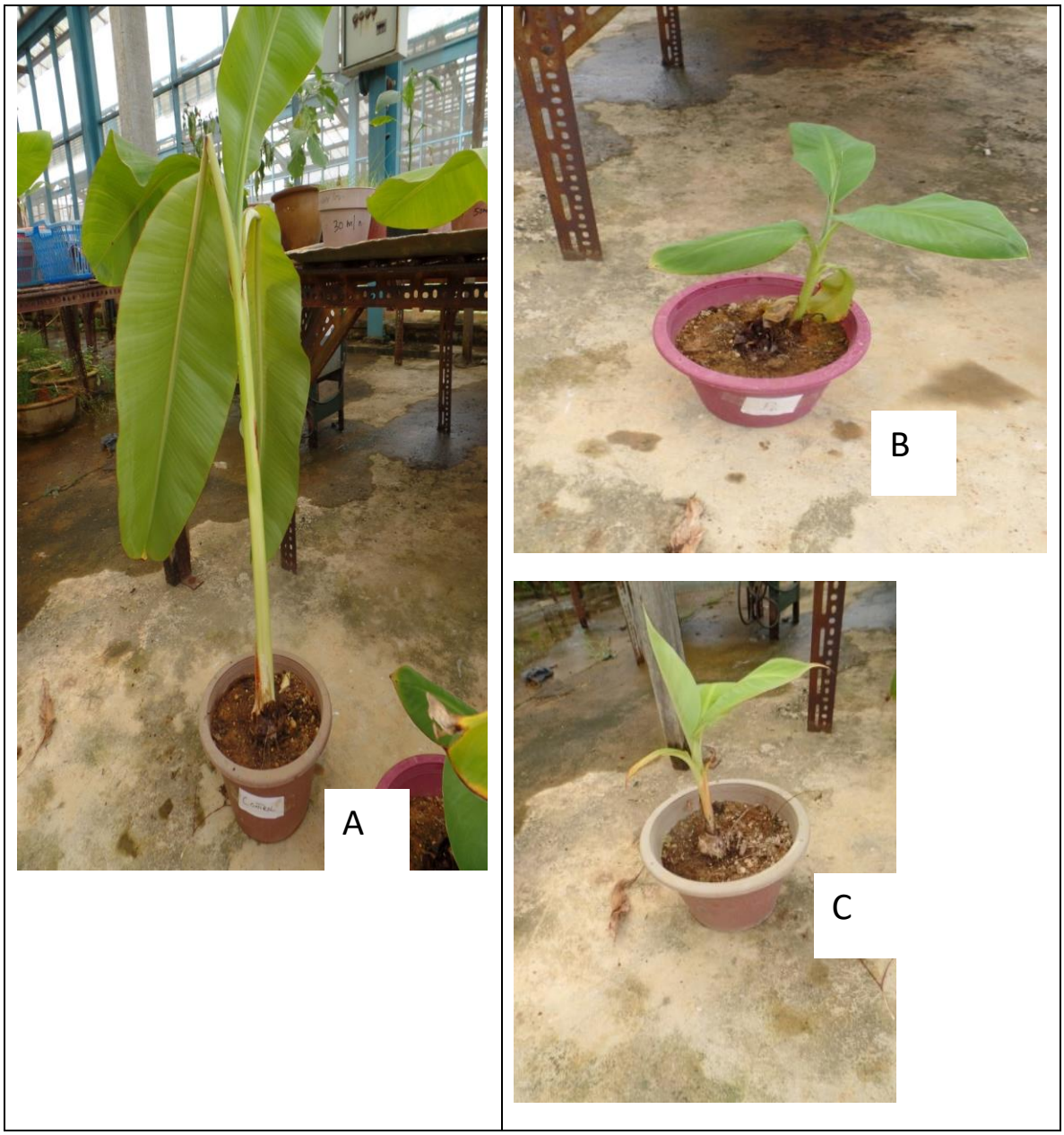

Figure 1: Above ground symptoms of *P. coffeae* (B), *M. incognita*(C) and control (A)

Figure 2: Below ground symptoms of (A) control, (B), *M. incognita*, (C) *P. coffeae* and (D) Mixed infection of A and B

For *Meloidogyne incognita*, the results presented in Table 2,show thattheranges of percentage reduction of plant parts were-25.8 to -56.3%, root length, -5.7 to -50%root weights, -32.9 to -65.7% shoot length,-32.9 to -65.7% shoot weight -38.2 to 62.7% compared to the control plants. Significant reduction ($P \leq 0.05$) was seen from various densities examined. Though, the significance was mostly in ranges between 100ni to 500ni on one hand and 1000ni to 3000ni on the other, and in few cases to 5000ni. In general, 5000 *P. coffeae* inoculum density recorded greater damages. All higher vegetative growth parameter damage was recorded at 5000 *Meloidogyne incognita* inoculum density and the least on the lower inoculum densities. The *P. coffea* recorded higher reduction in plant heights; leaf area and *pseudo stems*. Similarly, root length, weight and shoot length and weights both showed reduction at 5000 *P. coffeae* inoculum densities compared to the control plants.

Significant reduction ($P \leq 0.05$) was seen from the various inoculum densities examined. In general, reduction in vegetative growth parts were higher at

higher inoculum otherwise, inoculum densities were proportional to the reduction percentages across all densities. However, the significant differences among the inoculum densities were in the ranges of 100 to 500ni and 1000 to 3000ni and in some instances to 5000ni.

The result of pathogenicity trial in this study (Table 2) shows that *M. incognita* inoculum densities caused substantial damage to banana vegetative parts. There were significant differences among the treatments and the highest root length reduction of 37.7cm was recorded in P14, while the other treatments were not significantly different from each other as compared to the control P 14with 86.48 cm and the root weight followed the same trend. However, the shoot length and weight recorded significant reduction both in P7 and the rest were similar.

The present results are in agreement with the report of Pinochet *et al.*(1998) who reported banana damage by *Meloidogyne* spp in Canary Islands. Other workers also documented similar findings in North Africa, South Africa, West Africa, Martinique and in Brazil (Quénéhervé *et al*., 2000 and Cofcewicz *et al.*, 2001).

For the mixture of the two strains, the treatments differed significantly with treatment P15 recordingthe lowest root reduction of 7 5.54 cm and P17 recording the highest root reduction compared to the control plants. The trend was the same for the other measured parameters, except for shoot weight where there were no significant differences among the treatments compared with the control. The percentage reduction of the measured parameters as affected by *P. coffeae* and *M. incognita* ranges from-27.5 to – 53.1`% on plant height,-18.2 to -50.8%in leaf area, -20.3 to -57.2% *pseudo stems*,-12.6 to -40.3% root length, -9.7 to -96.1%shoot length and-25.2 to -68.9% shoot weight, compared to the control plant. Significant reduction ($P \leq 0.05$) was recorded from the various densities examined. In general, 5000 *P. coffeae/ M. incognita* inoculum density recorded higher effects on plant heights, leaf areas *pseudo stems*, root and shoot lengths and weights by reducing them drastically when compared to control plants.

The result shows that mixed population of *P. coffeae* and *M. incognita* inoculum densities caused substantial damage to banana vegetative parts in the same way they did individually. These results agree with the reports of De Waele and Davide (1998) that most local banana cultivars like Pisang Berangan (A.A, syn. Lakatan), Pisang Mas (AA, syn. Sucrier), Pisang Rastali (AAB, Silk subgroup), Pisang Nangka (AAB), Pisang Tanduk (AAB), and Pisang Embung (AAA, syn. Gros Michel) are good hosts to *M .incognita* either singly or in mix population with *P. coffeae* and others. Here they reduce *pseudo stems*, girth and plant height which are obviously seeingin the present study.

Disease severity

Reproductive factor (RF)

Results presented in Tables 4-6 show significant differences among the different inoculum densities with RF in proportion with the different densities. In both *P. coffeae* and *M. incognita*, lower RFs were recorded in 100ni and the highest in 5000ni respectively and same was observed in the mix populations. Similarly, root necrotic and galling indices followed the same trend with the RF increasing with increased inoculum densities.

From this study, increase in initial inoculum density resulted in increase in RF in all the treatments. Castillo *et al*. (2001) and DiVito *et al*. (2004) reported similar findings as obtained from this study. Reports that increasing initial nematode inoculum densities resulted in increased nematode reproductive levels have been documented on *Meloidogyne spp* infections on several crops. Kheir *et al*. (2004) reported proportional increase in final nematode population density of *M. incognita* with increase in initial inoculum densities on banana cultivars but observed that all densities suppressed banana growth. Contrary to result obtained from this study, Olabiyi *et al*. (2009) reported negative correlation of RF with *Meloidogyne spp*. to the initial inoculum density. The final *M. incognita* population increased proportionally with increase in initial population densities and all densities showed high damaging status.

Table 4: Reproduction and percentage root necrosis caused by different inoculumdensities of *Pratylenchus coffeae* on *Musaparadisiaca*

***Pratylenchus coffeae* population**	**Average number of nematodes**	**RF**	**Root lesion necrotic index (%)**
	Absolute mean population (200 cc soil+10 g root)		
Control	00	00	00
100nempop	23d	1.7d	5.10
250nempop	102.2d	2cd	5.70
500nempop	228d	2.2c	13.10

1000nempop	484d	2.4c	14.30
2000nempop	1359.6c	3.24b	21.00
3000nempop	2076.8b	3.4b	22.30
5000nempop	4052a	4.1a	45.80
MSD	**693.53**	**0.48**	

RF = Reproductive Factor.

Table 5. Reproduction and percentage root galling caused by different inoculation levels of *Meloidogyne incognita* on *Musa paradisiaca* at 12 WAI

***Pratylenchus coffeae* population**	**Average Number of Nematodes**	**RF=Pf/Pi**	**Root galling index (%)**
	Absolute mean population (200 cc soil+10g root)		
Control	00	00	00
100nempop	23d	1.7d	5.10
250nempop	102.2d	2cd	5.70
500nempop	228d	2.2c	13.10
1000nempop	484d	2.4c	14.30
2000nempop	1359.6c	3.24b	21.00
3000nempop	2076.8b	3.4b	22.30
5000nempop	4052a	4.1a	45.80
MSD	**693.53**	**0.48**	

RF = Reproductive Factor,

Table 6: Reproduction and percentage root necrosis caused by different inoculum densities of *Pratylenchus coffeae and Meloidogyne incognita* combined on *Musa paradisiaca*

***P. coffeae / M. incognita* populations**	**Average Number of Nematodes**	**RF**
	Absolute mean population (200ccsoil+10g root)	
Control	00	00
2000 Mix nem pop (*P. coffea*)	4432c	2.1d
‘’ (*M.*ingognita)	347.4c	1.8c
3000Mix nem pop *P. coffea*	940.8b	3ab
M.ingognita	853.6b	2.8b
5000Mix nem pop *P. coffea*	1721.4a	3.4a
*M.*ingognita	1518.8a	3ab
MSD	**238.75**	**0.43**

RF = Reproductive Factor

In the present report, root necrotic percentages due to *Pratylenchus coffeae* were greater than 5% in all the inoculum densities evaluated. This implies that the damage was high across the treatments. This agrees with the work of Speijer *et al*. (1994) who reported necrosis of root cortex above 5% as high. Coyne *et al*. (2007) and Peregrine and Bridge, (1992) described the extent of root cortical necrosis as a determinant of yield loss. Similarly, toppling is the outcome of the destruction of the root system of a plant by plant parasitic nematode (Barkeye *et al*., 2000). The highest percentage root necrosis score of 45%recorded from the 5000-inoculumdensity in this study indicates what banana growers will go through, when nematode population reaches this density on their farms.

On the other hand, galling severity in all the inoculum concentrations increased with increase in initial nematode population in the present study. This is in agreement with earlier report by Mekete *et al*. (2003) who showed that galling severity of tomato root and pepper increased with increase in initial inoculum density of *M. javanica*. Udo and Ugwuoke, (2010) reported that *M. incognita* recorded more pathogenic effect on turmeric plants with increased nematode density as more galls were recorded at higher inoculum densities compared to lower ones

CONCLUSION AND RECOMMENDATION

Tissue cultured *M. paradisiaca* plants were highly sensitive to *P. coffeae* and *M. incognita* diseases infecting their roots thus leading to significant suppression of the vegetative growth in the present study. Root lesion and galling indices showed higher disease severity at all inoculum densities evaluated. At both minimum 100ni and maximum 5000ni densities, damage to the test banana by the nematodes was severe. Future studies should involve screening of banana land races against these

nematodes with the view to developing resistant varieties to them for use by farmers.

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PERFORMANCE OF SOYBEAN GENOTYPES UNDER RHIZOBIA INOCULATION ACROSS THREE AGRO-ECOLOGICAL ZONES OF NIGERIA

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ABSTRACT
There is need to improve soybean yield productivity per unit area in the tropics, at least to the world average productivity level. To achieve this, attention has to be paid to the selection of high yielding and stable genotypes through plant breeding improvement programmes. Twenty four soybean genotypes were investigated across three agro-ecological zones (Southern Guinea savanna, Northern Guinea savanna and Sudan savanna) in Nigeria to determine their productivity. In each zone, the experiments were laid out in split-plot design with three replications. Data were collected on growth and yield parameters. Results indicated that, genotypes TGx 1987-10F, TGx 1990-55F, TGx 1990-46F, TGx 1990-57F, TGx 1989-49FN, TGx 1989-48FN, TGx 1989-40Fand TGx 1989-40F were high yielding across the three agro-ecological zones. This indicates that environmental differences could be responsible for soybean productivity from one agro ecology to another. Therefore, soybean genotypes should be recommended for cultivation across the environments. Appropriate soybean inoculation with LegumeFix and or NoduMax should be adopted in order to enhance soybean yield and productivity.

KEYWORDS: Soybean, Agro-ecology, Performance, Interaction

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume native to East Asia perhaps in North and Central China (Laswai *et al*., 2005) and belongs to the family Leguminosea. Soybean has been recognized as one of the premier agricultural crops today, thus it is the best source of plant protein and oil. It has now been recognized as a potential supplementary source of nutritious food (Wilcox and Shibles, 2001). It has been found to substitute other sources of good quality protein such as milk, meat and fish. Therefore, it has become very suitable compared to other protein sources that are scarce or too expensive to afford (Asrat *et al*., 2009).

Soybean contains a good quality protein of 42 % and 19.5 % oil (Wilcox and Shibles, 2001). Soybean protein is considered complete, because it supplies sufficient amounts of the types of amino acids that are required by the body for building and repair of tissues (Jinze, 2010). Essential amino acids found in soybean are methionine, isoleucine, lysine, cystine, phenylalanine, tyrosine, theonine, tryphophan as well as valine (Bellaloui *et al*., 2009). Amino acids are used in the formation of protoplasm, the site for cell division and therefore facilitate plant growth and development. Soybean has been found to have different uses; for example in food industry, soybean is used for flour, oil, cookies, candy, milk, vegetable cheese, leathin and many other products (Coskan and Dogan, 2011).

Improving soybean yield productivity per unit area is needed, at least, to the world average productivity level in the tropics. To achieve this, attention has to be paid to the selection of high yielding and stable genotypes through plant breeding/improvement programmes. In plant improvement programmes, knowledge of the genetic variability and the adequate eva1uation of breeding materials under several environments are of paramount importance. With the identification of high-yielding and well-adapted soybean genotypes, breeders can make recommendations to farmers, for soybean production in specific environments and across environments, which is expected to address the yield gap presently experienced in Nigerian agro ecologies. Therefore the objectives of the study were to evaluate the performance of soybean genotypes across environments, evaluate yield stability of the genotypes across the three environments and select superior advance genotypes in the test environments under rhizobia inoculation for yield evaluation.

METHODOLOGY

The study area: The experiment was conducted during the 2015 and 2016 rainy seasons at three experimental sites across three different agro-ecologies of Nigeria. The experimental sites were; Abuja located between latitude 9°16'N and longitude 7°20°E, in the Southern Guinea savanna, Igabi located between latitude 112°12'N and longitude 7°20°E in the Northern Guinea savanna, Gwarzo located between latitude 11°19'N and longitude 8°51°E in the Sudan savanna.

Treatments and experimental design: The experimental treatment of 24 soybean genotypes (TGx 1989-11F, TGx 1990-110FN, TGx 1989-42F, TGx 1990-95F, TGx 1989-45F, TGx 1990-114FN,

TGx 1989-53FN, TGx 1993-4FN, TGx 1989-75FN, TGx 1990-78F, TGx 1987-62F(Check), TGx 1448-2E(Check), TGx 1989-40F, TGx 1990 -52F, TGx 1989-48FN, TGx 1990-40F, TGx 1989-49FN, TGx 1990-57F, TGx 1989-68FN, TGx 1990-46F, TGx 1990-55F, TGx 1987-10F(Check), TGx 1835-10E(Check), TGx 1485-1D(Check) (Checks are already released genotypes)) and three inoculation types (Without Inoculation, LegumeFix and NoduMax) fitted into a Split-plot design with three replications. The main plots consisted of the soybean genotypes and the sub-plots were the inoculation types. Gross plot size was 3 m × 4 m (12 m^2) containing five ridges (3 m long) each. Net plot size was 3 m × 2.5 m (7.5 m^2). An alley of 1 m was used to separate the blocks, and 0.5 m for the treatment plots.

Agronomic practices: The experimental field in each location was ploughed, harrowed and ridged with tractor. Then followed by field layout in which 216 sub-plots were marked out according to the treatments. Single super phosphate (SSP) was applied at the rate of 40 kg P_2O_5 ha^{-1} at 2 weeks after sowing as basal fertilizer using side placement method of fertilizer application. Cypermethrin (Best) at the rate of 0.14 kg a.i ha^{-1} (Afolayan and Braimoh, 1991) was applied at 3 weeks after sowing on the seedlings with knapsack sprayer to control insect pests infestation. In each of the location and year of research, seed yield was taken in which seeds were separated from the husk and kept in labelled bags representing respective plots and then converted to kilogram per hectare.

Analysis: Data collected on growth parameters and seed yield were subjected to Analysis of Variance (ANOVA) using General Linear Model (GLM) procedure of SAS (SAS, 2003). Treatment of significance was determined at 5 %. Means were separated using Duncan Multiple Range Test at p = 0.05. Combined data was used for correlation. To determine genotypic sensitivity and stability, linear regression and correlation model was used (Eberhart and Russell, 1966). Additive Main Effect and Multiplicative Interaction (AMMI) were used to determine the stability pattern of the genotypes across the locations (Adie and Krisnawati (2015). The AMMI model is $Y_{ij.} = \mu + g_i + e_j + \sum \lambda_k \alpha_{ik} \gamma_{jk} + \varepsilon_{ij.}$

Where Y_{ij} is the mean of the ith line in the jth environment, μ is the grand mean, g_i is the genotype effect, e_j is the site effect, λ_k is the singular value for principal components k, α_{ik} is the eigenvector score for genotype i and component k, γ_{jk} is the eigenvector score for environment j and component k, and $\varepsilon_{ij.}$ is the error for genotype i and environment j.

RESULTS AND DISCUSSION

Mean seed yield of soybean as affected by genotypes and inoculation during the 2015 and 2016 cropping seasons across the environments is presented in Table 1. Seed yield was significant among the genotypes and the inoculation applications at both cropping seasons and their combined (the average of 2015 and 2016 cropping season data for each treatment) data. TGx 1990-110FN, TGx 1990-46F, TGx 1989-45F, TGx 1989-49FN and TGx 1990-55F recorded significantly higher seed yield during the 2015 cropping season while TGx 1990-95F was significantly lower in yield during the same cropping season. In 2016 cropping season, TGx 1990-46F produced the highest yield but not significantly different from TGx 1835-10E(Check), TGx 1485-1D(Check), TGx 1989-49FN, TGx 1989-45F and TGx 1990-110FN. Also, the combined data revealed that, TGx 1990-46F and TGx 1984-49FN had significantly higher seed yield than the other genotypes. Plants without inoculation produced significantly lower seed yield in both cropping seasons. Furthermore, the interaction between genotypes and inoculation was not significant except during the 2016 cropping season. Seed yield were generally higher in plants inoculated with either NoduMax or LegumeFix compared to those plants without inoculation (Table 2). Among the inoculated plants, irrespective of the inoculants, TGx 1990-110FN, TGx 1989-49FN and TGx 1990-46F produced significantly higher yield, similar to those produced by NoduMax-inoculated TGx 1989-48FN, TGx 1990-40F and the LegumeFix-inoculated TGx 1989-42FN, TGx 1989-68FN and TGx 1990-55F plants. These were similar in yield as the checks TGx 1835-10E, TGx 1835-10E, TGx 1967-62F and TGx 1987-10F (Table 2). In the combined data, all the growth and yield attributes measured correlated positively and significantly with the seed yield (Table 3). The strongest relationship in the combined data, was that between 100-seed weight and seed yield (r = 0.889*). This was in turn also the strongest relationship between any two growth parameters recorded. Table 4 shows the sensitivity and stability coefficients for seed yield of soybean genotypes across environments during the 2015 and 2016 cropping seasons. TGx 1989-19F recorded mean seed yield (1577 kg ha^{-1}) greater than average mean 1570 kg ha^{-1} and showed average genotypic sensitivity (b = 1) hence averagely stable. Also, five genotypes TGx 1990-40F, TGx 1989-11F, TGx 1990-52F, TGx 1448-2E(Check) and TGx 1990-55F recorded more than mean performance and above average sensitivity, thus less stable. Furthermore, four genotypes, TGx 1989-45F, TGx 1989-75FN, TGx 1990-110FN and TGx 1990-95F had more than mean performance and below average sensitivity (b < 1) making it more stable.

The genotype and environment interaction clearly plays a significant role in breeding adaptable genotypes to the wide environment. These results agree to the findings of Gebeyehu and Assefa (2003) who reported that selections based on the highest yielding genotypes appeared less stable than the average of all genotypes. Furthermore, Gebeyehu and Assefa (2003) stated that selection solely for seed yield could result in rejection of several stable genotypes. TGx 1989-45F and TGx 1990-110FN out yielded others because of its yield components such as plant height, number of leaves, number of pods per plant and some other growth traits that have contributed to the high yield. The mean performance (Table 1) revealed that high yielding genotypes across the environments over the two years were TGx 1989-45F, TGX 1990-110FN and TGx 1989-53FN. Thus, the outstanding performance by TGx 1989-45F in terms of yield made it the best performer across the three environments over two years. These conform to Egli (1998) explanation for soybean performance that yield variation across environments and years was associated with changes in number of seeds per unit area. A contrary explanation is that an ideal soybean cultivar is one that achieves the greatest yield across many environments (Fasoula and Fasoula, 2002). Thus, the genotype by environment interaction might have made it difficult for breeders to identify the best genotypes, during selection and recommendation. The positive and significant correlation estimated between seed yield and other traits agreed with the findings of Malik *et al*. (2006). This implies that selections aimed at increasing seed yield would invariably select for higher plant height, higher leaf number and earliness to flower. This finding was in agreement with Karasu *et al*. (2002) who revealed that crop yield variations are strongly influenced by growth and yield parameters. The highest and the lowest seed yields level attained by the genotypes were mostly due to plant height, number of leaves, number of branches per plant and number of pods per plant. In this study, it could be cited that the correlation coefficient of the genotypes across the environments in two years indicated that plant height had significant correlation with seed yield. This finding conformed to the report of Rajanna *et al*. (2000). The chlorophyll content was significantly associated with seed yield. This indicated that with the greenish nature of the leaves more efficient utilization of solar radiation could be achieved. The finding was in agreement with Kumudini *et al*. (2001) who explained that the higher the chlorophyll content, the more improved the yield due to increased intercepted solar radiation and enhanced carbon exchange rate. The little variability recorded among genotypes was due to their response to climate changes in the three environments. This agrees with Kang (2002) findings that environment played major role in phenotypic expressions of agronomic traits. To overcome genotype by environment effect, Cucolotto *et al*. (2007) partitioned genotype by environment interaction into two; adaptability and phenotypic stability. These researchers defined adaptability as the capability that a genotype has to make use of the environmental effects that warrants a high yield level and phenotypic stability was related to yield maintenance or yield predictability in diverse environment. However, in the present study, genotype by environment was not partitioned. Phenotypically, all the studied genotypes followed similar trend of performance over two years. According to Eberhart and Russell (1966), an ideal cultivar would have both a high average performance over a wide range of environments plus stability. Although genotypic main effect was highly significant this shows difference in genotypic performance across environments resulting in genotype by environment interaction. The existence of genotype by environment interaction raised the need to identify stable and high yielding genotypes.

Table 1: Mean seed yield (kg ha^{-1}) of soybean genotypes as affected by inoculation during the 2015 and 2016 cropping seasons across the environments

Treatment	2015	2016	Combined
Genotypes (G)			
TGx 1989-11F	1659.2cd	1545.1dc	1602.1c
TGx 1990-110FN	2717.5a	1839.0ab	2278.3a
TGx 1989 -42FN	1590.6cd	1676.5bc	1633.6c
TGx 1990 -95F	1514.2d	1544.6cd	1529.4c
TGx 1989-45F	1989.8ab	1820.1ab	1905.0ab
TGx 1990-114FN	1558.8cd	1611.3cd	1585.0c
TGx 1989-53FN	1613.0cd	1498.9d	1556.0c
TGx 1993-4FN	1581.8cd	1601.0cd	1591.4c
TGx 1989-75FN	1573.1cd	1592.3cd	1582.7c
TGx 1990-78F	1563.6cd	1582.8cd	1573.2c

TGx 1967-62F(Check)	1722.7bc	1738.6bc	1730.7bc
TGx 1448-2E(Check)	1658.7cd	1655.7bc	1657.2c
TGx 1989-40F	1583.3cd	1647.0bc	1615.2c
TGx 1990-52F	1657.3cd	1693.2bc	1675.3c
TGx 1989-48FN	1752.9bc	1816.5bc	1784.7bc
TGx 1990-40F	1699.1bc	1762.7bc	1730.9bc
TGx 1989-49FN	1996.4ab	1982.3ab	1989.4ab
TGx 1990-57F	1707.4bc	1771.1bc	1739.2bc
TGx 1989-68FN	1696.7bc	1727.0bc	1711.9bc
TGx 1990-46F	2060.0a	2145.9a	2102.9a
TGx 1990-55F	1859.5ab	1801.0bc	1830.2bc
TGx 1987-10F(Check)	1741.8bc	1794.4bc	1768.1bc
TGx 1835-10E(Check)	1743.7bc	1851.9ab	1797.8bc
TGx 1485-1D(Check)	1753.0bc	1872.2ab	1812.6bc
SE±	112.7	109.3	122.2
Inoculation(I)			
Without inoculation	1204.0c	1250.2b	1239.7c
NoduMax	1882.1b	1912.8a	1892.0b
LegumeFix	1988.1a	2008.3a	1991.0a
SE±	38.3	42	39.5
Interaction			
G x I	NS	*	NS

Means followed by the same letter(s) within a set of treatment column are not significantly different at P=0.05 using DMRT; NS= Not significant;
*= Significant at P=0.05; SE = Standard error of the mean

Table 2: Interaction effect of genotypes and inoculation on the seed yield (kg ha^{-1}) of soybean during the 2016 cropping season across the environments

Genotypes	Without inoculation	NoduMax	LegumeFix
TGx 1989-11F	1189.1j	1530.9f	1915.2b
TGx 1990-110FN	1299.4i	2118.3a	2099.3a
TGx 1989 -42FN	1236.1i	1777.5d	2016.0a
TGx 1990 -95F	1185.6j	1836.3c	1611.8e
TGx 1989-45F	1122.7j	1965.6b	1772.1d
TGx 1990-114FN	1172.6j	1746.4d	1915.0b
TGx 1989-53FN	1158.9j	1701.9d	1636.0e
TGx 1993-4FN	1197.9j	1828.7c	1776.4d
TGx 1989-75FN	1270.5i	1743.7d	1762.6d
TGx 1990-78F	1181.5i	1696.4e	1870.7c
TGx 1967-62F(Check)	1238.1i	1814.3c	2163.5a
TGx 1448-2E(Check)	1317.6h	1734.7d	1914.9b
TGx 1989-40F	1317.8h	1874.3c	1748.8d
TGx 1990-52F	1244.3i	1931.3b	1904.0b
TGx 1989-48FN	1345.6h	2125.2a	1978.7b
TGx 1990-40F	1212.7i	2148.9a	1926.5b
TGx 1989-49FN	1168.3j	2229.3a	2549.3a
TGx 1990-57F	1329.9h	1904.0b	2079.1a
TGx 1989-68FN	1341.6h	1759.0d	2080.3a

TGx 1990-46F	1326.8h	2588.8a	2521.9a
TGx 1990-55F	1144.8i	1911.6b	2346.3a
TGx 1987-10F(Check)	1314.1h	1987.0b	2081.8a
TGx 1835-10E(Check)	1245.0i	2025.7a	2284.7a
TGx 1485-1D(Check)	1443.7g	1929.2b	2243.7a
SE±		88.2	

Means followed by the same letters are not significantly different at P=0.05 using DMRT; SE = Standard error

Table 3: Correlation matrix between growth and yield attributes against seed yield of some soybean genotypes as influenced by inoculation type during the 2015 and 2016 cropping seasons across environments

	1	2	3	4	5	6	7	8	9	10
1	1									
2	0.564*	1								
3	0.621*	0.719*	1							
4	0.581*	0.603*	0.709*	1						
5	0.156*	0.298*	0.253*	0.186*	1					
6	0.599*	0.696*	0.752*	0.589*	0.240*	1				
7	0.599*	0.696*	0.752*	0.589*	0.240*	0.000*	1			
8	0.242*	0.335*	0.340*	0.307*	0.145*	0.333*	0.333*	1		
9	0.478*	0.424*	0.539*	0.393*	0.177*	0.455*	0.455*	0.199*	1	
10	0.591*	0.597*	0.696*	0.509*	0.234*	0.789*	0.789*	0.264*	0.889*	1

*= Significant at 5%, 1= Chlorophyll content, 2= Plant height, 3= Number of leaves, 4= Number of pods per plant, 5= Number of branches per plant, 6= Above ground biomass yield, 7= Total biomass yield, 8= Harvest index, 9= 100-seed weight, 10= Seed yield

Table 4: Combined analysis for sensitivity and stability coefficients for seed yield from soybean genotypes across environments during the 2015 and 2016 cropping seasons

Genotype	Mean	Sensitivity (b value)	Static Stability	Mean square Deviation
TGx 1989-53FN	1493	0.7377	62849	909
TGx 1989-45F	1631	0.7381	64383	3846
TGx 1989-75FN	1571	0.8235	79986	12118
TGx 1990-114FN	1539	0.8239	83799	4325
TGx 1990-110FN	1594	0.8509	91675	17353
TGx 1485-ID(CK)	1570	0.8553	98997	32982
TGx 1993-4FN	1564	0.9010	100316	19412
TGx 1989-68FN	1537	0.9180	100367	7392
TGx 1990-78F	1488	0.9270	102786	973
TGx 1989-42F	1568	0.9485	104917	3565
TGx 1987-62F(CK)	1585	0.9533	105135	1887
TGx 1835-10E(CK)	1567	0.9676	118586	22522
TGx 1990-95F	1607	0.9848	118601	61738
TGx 1989-40F	1577	1.0000	124557	4196
TGx 1990-40F	1592	1.0414	136271	426
TGx 1989-11F	1579	1.0881	139353	18149
TGx 1987-10F(CK)	1566	1.0900	142051	125
TGx 1990-52F	1587	1.0970	144824	2772
TGx 1448-2E(CK)	1596	1.1146	146514	8178
TGx 1990-55F	1632	1.1271	149189	7093
Grand mean	1570			

CK= Check

CONCLUSION AND RECOMMENDATIONS

Out of the twenty-four genotypes evaluated for genotype by environment interaction and yield

stability, TGx 1987-10F, TGx 1990-55F, TGx 1990-46F, TGx 1990-57F, TGx 1989-49FN, TGx 1989-48FN, TGx 1989-40F and TGx 1989-40F were identified by the analytical tools used as the overall best in relation to seed yield and stability as compared to the grand mean performance of the genotypes. The performance of inoculated seeds by B. *japonicum* was statistically higher than that without inoculation seeds. Therefore, symbiotic N_2 requirement and optimum yield potential of soybean genotypes grown in the savanna region of Nigeria may be met by rhizobia population. Therefore, soybean genotypes should be recommended for cultivation across the environments. Appropriate soybean inoculation with LegumeFix and or NoduMax should be adopted in order to enhance soybean yield and productivity

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INCIDENCE AND POPULATION OF PLANT PARASITIC NEMATODES OF PEPPER *(CAPSICUM FRUTESCENS* L.) FROM THREE SELECTED VILLAGES IN MOKWA LOCAL GOVERNMENT, NIGER STATE, NIGERIA

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ABSTRACT
A survey was carried out from three village areas around Mokwa to investigate and determine the incidence and population of plant parasitic nematodes of pepper. A total of nine soil samples from pepper rhizosphere were taken 10 cm around the plants. The samples were extracted using White head tray method. From the supernatant's residue, a total of five genera of plant parasitic nematodes (PPNs) were identified. Thespecies Scuttelonema. bradyswas found to be predominant in the soil samples as it accounted for up to 45.34% of the overall nematode population with the population density (PD) of 365. This was followed by Helicotylenchus multicinctus with 38.50% and PD 310, Meloidogyne sp with 8.07%, Criconemela sp with 6.8 3% and Aphelenchoides sp with 1.24% was the least in occurrence. Both soil textural class and properties influenced nematode population distribution. The presence of these parasitic nematodes even at low populations in the soil is significant, as population build up can eventually result inthe reduction of crop yield. Based on the importance of the damages caused by these nematodes to pepper in the surveyed areas, it is important to train farmers on techniques of growing healthy seedlings, as well as conducting periodic soil and pathogenicity tests. These will assist the farmers to continue to grow nematodes - free pepper to improve their household income.
Key words: Incidence, Mokwa, nematodes, pepper, population

INTRODUCTION

Pepper (*Capsicum* sp) is one of the five most important vegetable crops used in Nigeria as condiment and food flavour (Paiko *et al*., 2019). The cultivation pepper has existed for several hundreds of years as a sustainable form of agriculture. Capsicum exists as an annual herbaceous vegetable or perennial shrub of the Solanaceae family (Amusa *et al.,* 2004). It is a spice grown in both tropical and sub-tropical regions (Than *et al.,* 2008). Pepper is also suitable for the diets of the obsessed and is useful in the control of cancer of the stomach and colon (Pamplona-Roger, 2007).

Peppers are low in sodium, cholesterol free, rich in vitamins A and C, and are a good source of potassium, folic acid and vitamin E (Than *et al.,* 2008). Fresh green peppers contain more vitamin C than citrus fruits and fresh red peppers have more vitamin A than carrots (Than *et al.,* 2008). Sauces, soups, stews are generally made from Capsicum fruits and it is also used as flavouring agent (Amusa *et al.,*2004, Paiko *et al*., 2019). Varieties of pepper provide income for farmers who cultivate it in substantial quantities (Amusa *et al.,* 2004).

The domestic demand for pepper has increased over time which has resulted in the decline in its quantity for exportin several producing countries (Abubakar, 2015). This prompts the need to increase the supply of pepper at the farmer's level to beef up the quantity at the domestic level and to give room for export.

Nigeria is known to be one of the major producers of pepper in the world accounting for about 50% of the African production and the major area of production is Northern Nigeria (Paiko *et al*., 2019).It is important to note that in spite of the production level of pepper in Nigeria, importation of Pepper still continues (Abubakar, 2015). General increase in pepper yield in Nigeria can be enhanced by the cultivation of improved cultivars, and intensification of cultural practices and disease management.

Parasitic nematodes alone or in combination with other factors reduce pepper crop productivity and they cause farmers and nurserymen thousands of naira losses due to poor quality crop annually (Pokharel *et al.,* 2009).

Despite the importance of pepper to the national economy, limited attention is paid to problems limiting its production. In general, plant health problems, particularly those caused by nematodes have been neglected. Nematodes are well known as one of the most important diseases limiting vegetable production (Pokharel *et al.,* 2009). There is dearth of reports on the plant parasitic nematodes

of pepper in Niger State. Early identification and listing of plant pathogens in an area allows for timely development of management strategies for them. This goes a long way in avoiding epiphytotics and severe crop losses. It also checks the spread of many plant parasitic nematodes diseases and ensures the prevention of their spread to new areas.This work was, therefore, carried out to determine the incidence and population of plant parasitic nematodes in infested pepper (*Capsicum annum* L.) from three selected villages in Mokwa Local Government, Area of Niger State, Nigeria.

METHODOLOGY

Description of experimental location

The experiment was carryout at the Training and Research Plot of the Pest Management Technology Department, Niger State College of Agriculture, Mokwa located on Latitude 9.3044 ^{o}N and Longitude 5.06 6^{o}E of the Equator. Mokwa lies in the Southern Guinea Savanna agro-ecological zone. The average temperature in Mokwa is 27.6 °C. Precipitation averages 1149 mm and is bimodal in nature with two rain peaks in a raining season in June and August. The least amount of rainfall occurs in September and the average in the month is 1 mm. In August, the precipitation reaches its peak, with an average of 242 mm. The temperatures are highest in April, at around 30.5 °C. On the average, August is the coldest month of the year, with average temperature of 25.5 °C.

Sampling site and soil samples collection

A survey of infested pepper plants was conducted in three selected villages namely: Mokwa, Bokani and Jagi. From each village, three farms were tagged; 1, 2 and 3 and sampled. Soil samples were taken from the rhizosphere of plants by digging a hole near the base of the roots,10 cm deep following the procedure of Duong *et al*. (2015). Soil samples were collected randomly from plants showing symptoms of retarded growth and 15 soil cores were collected in a "W" pattern using a hand Trowel. The samples from each farm were thoroughly mixed in a 10-liter bucket, after which 500 g was taken as composite sample and put in labeled polyethylene bags following Speijer and De Waele (1997) procedural guidelines. They were then sealed tightly and labeled with details of host, locality and date of collection. A total of nine composite soil samples were collected in all.

Nematode extraction

White head tray method as described by Whitehead and Hemming (1965)was used for recovering nematodes from the soil samples. From each bulk sample, 200 g of soil sub-sample was wrapped in two layers of facial tissue and placed in a tray on top of a mesh. Approximately 200 ml of water were added to the pan, until the mesh was slightly covered with water and the soil contacts the water for 24 hoursto allow the nematodes crawl out of the soil. To count the nematodes, the triplicate of 1 ml from 100 ml homogenised suspension was taken into Huxley nematode counting slide and observed under a compound light microscope with under 10x magnification on Nikon's Eclipse 50i microscope (Kent, WA) according toSpeijer and de Waele, (1997). Average of the three counts was expressed as the mean population of the nematodes per 200 g or 100 ml. Nematodes were identified based on morphology and different species occurrences were recorded.

Rizosphere soil properties

Each of the remaining soil samples was sieved with a mesh of 2 mm size and air-dried for texture analysis following the method of Bouyoucos hydrometer (Gee and Or, 2002) The pH was measured *in situ* using pH meter while organic matter was determined using ignition method.

Data analysis

Absolute frequency and absolute density of the nematodes were calculated using method of AbdulRahman *et al*. (2014):

$$\text{Absolute frequency} = \frac{e}{n} \text{x } 100,$$

Where e = total number of samples containing a given nematode and

n = total number of samples at a given site and

$$\text{Absolute density} = \frac{\text{Number of nematodes in all samples}}{\text{Number of samples collected}} x100$$

RESULTS AND DISCUSSION

Table 1 shows the areas surveyed for plant parasitic nematodes associated with pepper plant in Mokwa. Five nematode species /genera namely *Helicotylenchus multinctus*, *Scutellonema bradys*, *Meloidogyne* sp. ,*Aphelenchoides sp*, and *Criconemela sp* were isolated from soils of pepper plants from nine sampling sites in Mokwa, Niger State, Nigeria.

Of the five species/genera obtained, *S. bradys* was found to be predominant in the soil samples as it accounted for up to 45.34% of the overall nematode population with population density (PD)of 365. It was followed by *Helicotylenchus multicinctus* with 38.50% and PD of 310, *Meloidogyne sp* with 8.07%, *Criconemela sp* with 6.83 % and *Aphelenchoides sp* with 1.24% which was the least in occurrence (Fig. 1)

Estimated Gross margin analysis for melon production under sole cropping system: The estimated gross margin analysis for melon

production under sole cropping system is shown in Table 1.

Estimated Gross margin analysis for melon production under mixed cropping per hectare: The estimated gross margin analysis for melon under mixed cropping system per hectare is shown in Table 2. The Table showed that cost of hired labor constituted 30.67 % of the total cost of production followed by seed cost, herbicides and fertilizers with 1.27, 20.54 and 10.54%, respectively. The net farm income accounted for ₦44,620.94. Also, the return on a Naira invested was ₦1.84 while gross and operating ratios were 0.57 and 0.35 respectively. All the ratios were less than 1 indicating profitability of melon production under mixed cropping system.

Table 1: Areas sampled for plant parasitic nematodes associated with pepper plants

VILLAGES	LOCATIONS	LAT.	LONG.	NEMATODES GENUS	POPULATION DENSITY
Mokwa-	FARM-1	9.3027866ºN	5.0468195 ºE	*Helicotylenchusmulticinctus*	25
				Scutellonemabradys	45
	FARM-2	9.2955367ºN	5.0468195º E	*Helicotylenchusmultinctus*	25
				Scutellonemabradys	35
				Meloidogyne sp.	10
				Aphelenchoidessp	5
	FARM-3	9.3044968ºN	5.0758915ºE	*Helicotylenchusmultinctus*	10
				ScutellonemaBradys	10
				Meloidogynes sp.	80
				Criconemelasp	25
BOKANI	FARM-1	9.2962536VN	5.05377244ºE	*Helicotylenchusmultinctus*	60
				Scutellonemabradys	25
				Meloidogyne sp.	10
				Aphelenchoidessp	5
	FARM-2	9.21877933ºN	5.0400533ºE	*Helicotylenchusmultinctus*	5
				Scutellonemabradys	10
				Meloidogynessp	5
	FARM-3	9.2983686ºN	5.072093338ºE	*Helicotylenchusmultinctus*	20
				Scutellonemabradys	50
				Criconemelasp	30
JAGI	FARM-1	9.15941166ºN	5.23994166ºE	*Scutellonemabradys*	20
				Meloidogyne sp	20
	FARM-2	9.11581666ºN	5.21554166ºE	*Helicotylenchusmultinctus*	5
				Scutellonemabradys	15
	FARM-3	9.11175499ºN	5.215418333ºE	*Helicotylenchusmultinctus*	160
				Scutellonemabradys	86
				Meloidogyne sp	10

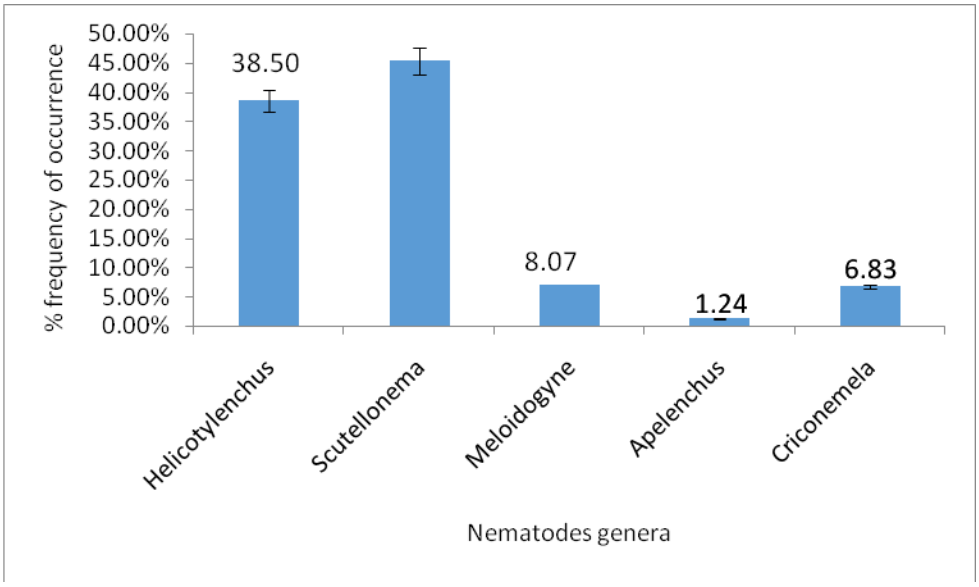

Fig.1:Frequency of occurrence of nematode genera isolated from soil rhizosphere of pepper plants from Mokwa.

Figure 2: shows that Jagi village recorded the highest population density of nematodes with 39.13% followed by Mokwa with 33.50% and Bokani with the least population density of 27.32%.

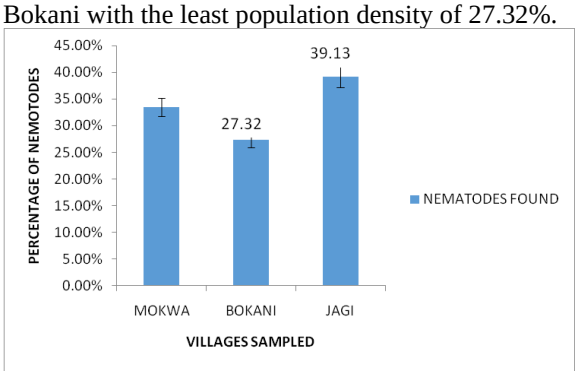

Fig.2.Percentage population of nematodes collected from three villages in Mokwa.

Soil properties influencing phytoparasitic nematode population on pepper

The relationship between nematode species and some soil properties is shown in Tables 2 and 3. The result shows that there was significant relationship between soil properties and nematodes population. Soil pH value between the ranges 6.49 to 7.2 greatly influenced nematodes abundance, while lower pH of 5.32 to 6.26 did not support nematode abundance. Soil organic matter (OM) content of 7.03% supported higher nematode population (NP) density of 255, while OM of 4.83 and 4.88% supported lower nematodes population density of 20 respectively. Generally, there was positive correlation between OM and NP (Table 3). Similarly, soil moisture content of 4.6% favoured higher nematode population and lower population was recorded from moisture content of 1.68% (Table 2). Among the soil textural classes, sandy clay loam soils supported higher nematodes population while clay and clay loam soils recorded low nematodes population (Table 4)

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Table 2: Soil properties influencing phytoparasitic nematode population on pepper

VILLAGE	LOCATIONS	pH	Organic matter (%)	Moisture Content (%)	Nematode pop
Mokwa-	FARM-1	6.62	3.13	2.18	70
	FARM-2	6.92	1.82	1.10	75
	FARM-3	7.2	2.08	0.99	125
BOKANI	FARM-1	5.32	2.78	1.18	100
	FARM-2	6.26	4.83	3.04	20
	FARM-3	6.85	3.69	1.86	100
JAGI	FARM-1	5.65	3.49	1.27	40
	FARM-2	6.16	4.88	1.68	20
	FARM-3	6.49	7.03	4.60	255

Table 3: Correlation matrix for soil roperties on nematodes population

	pH	OM	MC	NP
pH	1	0.6522*	0.8944*	0.5141*
OM		1	0.0013	0.2898
MC			1	0.1159
NP				

* - Correlation values are significant at $p < 0.05$

The correlation coefficient (r) indicated the relationship between soil properties and nematodes population

Table 4: soil textural class from samples collected in three villages of Mokwa

VILLAGE	LOCATIONS	Total (microns)			Soil textural class	Nematode population
		Clay (<2)	Silt (2–50)	Sand (>50)	(USDA)	
Mokwa-	FARM-1	37.18	19.05	43.76	Clay loam	70
	FARM-2	31.67	11.37	56.92	Sandy clay loam	75
	FARM-3	28.29	8.10	63.58	Sandy clay loam	125
BOKANI	FARM-1	31.31	9.21	59.44	Sandy clay loam	100
	FARM-2	41.69	31.78	26.48	Clay	20
	FARM-3	31.48	37.51	30.99	Clay loam	100
JAGI	FARM-1	34.12	25.32	40.54	Clay loam	40
	FARM-2	22.45	22.59	54.92	Sandy clay loam	20
	FARM-3	31.15	20.42	48.38	Sandy clay loam	255

The prevalence of the most economically important pepper nematode, *S. bradys* was documented in this study. The results of the present study contradict that reported by Adamou *et al*. (2013) where *Meloidogyne sp* population was found to be rather localised instead of being widespread in pepper farms as earlier reported by the workers. In our study, *Meloidogyne sp.* was found in only few locations and in lower quantity. The second most important parasitic genus was *Helicotylenchus.* The present report is in agreement with that by Mokbel *et al*. (2006) who found 9 phytoparasitic nematode genera to be associated with soil samples got from vegetable crops. The results show that the surveyed peppers were earnestly infected by nematodes in all the sites of the three villages. Five plant parasitic nematode genera were identified from our study.

The prevalence and wide distribution of nematodes across the study area may be due to an indiscriminate exchange of pepper seedlings among farmers from one locality to another. It was found that in the surveyed area, exchange of pepper and other vegetable seedlings is commonly practiced by the farmers.

The effects of soil physical and chemical properties on the nematode population were also investigated in the present study. Plant parasitic nematodes live their life cycles in the soil rhizosphere, which invariably impacts on their mobility dynamics,

breeding, parasitism and soil-root interaction (Fajardo *et al*., 2010, Myint *et al*., 2017). Geographical locations influence the effect a community of PPN has on crop which usually is dependent on agro-climatic conditions, host susceptibility, pathogenicity and other climatic factors (Baimey, 2009). According to Asif *et al*.(2015), seasonal fluctuation determines nematode population in a given area. Thus, nematode populations increase with season and nematode movement through large soil pore diameter and soil particle size with ease will be dependent on moisture. Soil texture is among the factors generally believed to influence PPNs species distribution. Certain species of PPNs prefer soils with higher oxygen content or lighter sandy soil to heavy ones, which may be connected to nematodes preference (Jibia *et al*., 2016). Studies carried out by (Baimey *et al*., 2009) showed that soil with different textural classes and chemical composition had influence on how soil physical and chemical properties affect nematode population distribution, density, and community structure. The results of the present study on soil textural classes agree with the reports by the above workers as the sandy loam textural class harboured more nematodes than the clay and clay loam classes.

In the present study, the result also agrees with the report by Thoden *et al*. (2012) who found an increase of plant parasitic nematodes with the addition of soil organic matter. Other workers, Akhtar and Malik (2000) and Thoden *et al*. (2012) found rapid increase in populations of free-living nematodes when organic amendments were added to the soil. In contrast, reduction in populations of plant parasitic nematodes was found when organic matter in the form of green manures or compost was added to the soil (Walker, 2004).

Similarly, the results of this study on pH is in agreements with earlier studies by Koen (1967) who observed that soil pH values 5.0-7.3, was not harmful to *Pratylenchus. brachyurus* but pH 1.0 was deadly. Also, according to Ardakani *et al.*, (2014), pH 7 supported abundance of *Tylenchulus. semipentrans* on citrus.

However, results on soil texture in this study are in most cases contradictory. Cadet *et al*. (2004) and Jaraba *et al*. (2007) opined that *Meloidogyne* gave abundance and higher frequency in sandy soils than clayey soils. Yet, Avendaño *et al*. (2004) pointed out that the population density of the same nematode genus was related to higher clay percentages. The differences on results illustrated that, other likely factors, suchas air porosity and structure among others, may influence the population of nematodes in soil.Thus the results of the present study agree with the reports by earlier workers and stresses that the predominance of the nematodes species from the sandy soils of most of the farms may be a consequence of low yields of pepper from farmers in the surveyed area.

CONCLUSION AND RECOMMENDATION

Results from this study have stablished the abundant occurrence of plant parasitic nematodes, which may consequently cause severe yield reduction in pepper. The findings show a rather lower distribution of plant parasitic nematodes, as only five genera were found from the rhizosphere of the pepper plants. The presence of genus *Meloidogyne* in lower frequency and localised to few locations contradict the widespread believe that *Meloidogyne* is the major nematode of pepper. This is the first documented report on distribution of PPNs associated with pepper in the study area. The presence of these nematodes even at lower densities in the soils is noteworthy as population build up may possibly result to crop yield reduction. Thus, further investigation should focus on the extent of pepper damage by these nematodes in Mokwa LGA to assist pepper farmers in their choice of farm locations to avoid nematode damage and or yield reduction.

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NUTRITIVE COMPOSITION AND HEALTH BENEFITS OF *MORINGA OLEIFERA* AND ITS ROLE IN AGRICULTURE

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ABSTRACT
Moringa oleifera is a plant with various uses and has gained recognition in many countries of the world due to its rich nutrient content and beneficial properties. This review article presents an overview of the nutritional constituents, anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties of Moringa. The various uses of Moringa in the agricultural sector were also highlighted. However, many value-added products are yet to be developed from Moringa value chain, if well exploited and utilized Moringa has great potentials to boost agricultural production. Moringa oleifera leaf contains 22.42 to 29.68% crude protein, 7.54 to 14.60% ash, 3.00 to 6.40% ether extract, 10.10 to 21.00% crude fibre, 92.12 to 93.60% dry matter and 37.87 to 49.60% nitrogen free extract. Moringa leaves have higher levels of the essential amino acids than other parts of the plant. It is noteworthy, that Moringa leaf meal contains significant quantities of essential amino acids that are rare in cereals and tubers. The plant is also a rich source of minerals and vitamins. Interestingly, there are vast areas of research on Moringa yet to be exploited. Many researchers have attested and documented that the inclusion of Moringa oleifera in human and animal diet has nutritional and several other good effects. Some important health properties associated with the use of Moringa are; anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties. All parts of the Moringa plant have been found to be very useful in the agricultural sector especially in animal production, crop production, agroforestry, aquaculture and food processing and product development.

Keywords: *Moringa oleifera,* agriculture, beneficial properties, nutritional content

INTRODUCTION

Drumstick tree (*Moringa oleifera*) is a unique plant that is referred to be nature's gift. It is categorized as a medium-size tree, found in many countries of the world (Gandji *et al*., 2018). *Moringa* plant is endowed with several properties and components that are advantageous in food and industrial applications. Basically, all parts of the *Moringa* plant have been used for several purposes. However, the most popular or commonly used part of *Moringa* plant is the leaf (Abbas, 2013). It is also a majorly used part for feeding animals. Several researchers have documented the nutritional, industrial, agricultural and medicinal uses of *Moringa oleifera*. *Moringa* is also well known to be a plant of significant economic importance. It is also among one of the most important plants used for food and folklore medicine. It is worth noting that this special plant is loaded with bioactive compounds that are beneficial to both man and animal. Some important properties exhibited by *Moringa* are; anthelmintic, antimicrobial, antioxidant and anti-inflammatory properties. The leaves and green fresh pods of *Moringa oleifera* are used as vegetables by humans in Central Africa, the have a good profile of amino acids and are rich sources of ascorbic acid and carotene (Fahey, 2005).

Moringa oleifera has a wide range of adaptation from arid to humid climates with the prospects of being grown in a wide range of ecological zones (Gadzirayi and Mupangwa, 2014). It is also cultivated with ease and it is characterised by fast growth (Martin, 2015). The objective of this paper is to provide a detailed review from relevant research studies on the nutritional potential and beneficial properties of the *Moringa oleifera* plant and its role/uses in various aspects of agriculture.

Nutrient Content of *Moringa:* *Moringa oleifera* seeds are rich sources of dietary minerals, proteins, and fats (Compaoré *et al*., 2011). Sánchez-Machado *et al*. (2010) analysed the chemical composition of the flowers, immature pods and leaves of *Moringa oleifera* and reported that the leaf had the highest content of lipid (4.96%), protein (22.42%) and ash (14.60%).
The proximate content of *Moringa oleifera* leaf is presented in Table1. The crude protein, ash, ether extract, crude fibre, dry matter, nitrogen free extract ranged from 22.42 to 29.68%, 7.54 to 14.60%, 3.00 to 6.40%, 10.10 to 21.00%, 92.12 to 93.60% and 37.87 to 49.60%, respectively (Table 1).

The nutritional composition of *Moringa oleifera* may differ depending on the proportion of the twigs, small branches mixed with leaves in the leaf meal (Mahmoud, 2013). The variation in the nutritive value of the *Moringa* leaf meal may also be attributed to soil fertility and type, agro-ecological zone where it is planted, age of plant or leaves, frequency of harvest, ecotype and cultivar, condition of handling and storage (Sánchez -Machado *et al*., 2010; Sultana *et al*., 2015).

Table 1: Proximate Composition of *Moringa oleifera* Leaf (Dry Matter Basis)

Parameter	Composition (%)	References
Crude protein	28.00	Okiki *et al*. (2015)
	29.68	Fadiyimu *et al*. (2010)
	26.79	Mabruk *et al*. (2010)
	25.10	Makkar and Becker (1996)
	22.90	Sena *et al*. (1988)
	26.40	Abbas (2013)
	22.42	Sánchez-Machado *et al*. (2010)
	23.51	Nouman *et al*. (2014)
	22.60	Tijani *et al*. (2016)
Ether extract	6.40	Mabruk *et al*. (2010)
	4.96	Sánchez-Machado *et al*. (2010)
	3.00	Nouman *et al*. (2014)
	3.40	Tijani *et al*. (2016)
	5.78	Fadiyimu *et al*. (2010)
	3.88	Okiki *et al*. (2015)
Ash	7.54	Fadiyimu *et al*. (2010)
	8.87	Abbas (2013)
	13.89	Mabruk *et al*. (2010)
	14.60	Sánchez-Machado *et al*. (2010)
	13.50	Nouman *et al*. (2014)
	7.90	Tijani *et al*. (2016)
	9.82	Okiki *et al*. (2015)
Crude fibre	21.00	Mabruk *et al*. (2010)
	12.57	Okiki *et al*. (2015)
	10.10	Tijani *et al*. (2016)
	16.98	Fadiyimu *et al*. (2010)
Dry matter	93.00	Mabruk *et al*. (2010)
	92.40	Nouman *et al*. (2014)
	93.60	Tijani *et al*. (2016)
	92.46	Fadiyimu *et al*. (2010)
	92.12	Okiki *et al*. (2015)
Nitrogen free extract	49.60	Tijani *et al*. (2016)
	40.11	Fadiyimu *et al*. (2010)
	37.87	Okiki *et al*. (2015)

The amino acid profile of *Moringa oleifera* leaf is shown in Table 2. *Moringa* leaves have higher levels of the indispensable amino acids (Gopalan *et al*., 1982; Fuglie, 2001; Fahey, 2005) which are more than those recommended by the Food and Agriculture Organization (FAO), this amino acid balance is a rare occurrence in plants (Paliwal *et al*., 2011). *Moringa oleifera* leaves contain more amino acid concentration than other parts of the tree (Sánchez-Machado *et al*., 2010). The total amino acid concentration in *Moringa oleifera* leaves was about twice that of the flowers (Sánchez-Machado *et al*., 2010).

According to Moyo *et al*. (2011), the high nutrient content level of the dried leaves of *Moringa oleifera* suggests its indispensable role as a potential feed resource in the near future. On the other hand, the anti-nutritional factors present in *Moringa oleifera* leaves are low and negligible (Moyo *et al*., 2011).
Moringa oleifera leaf is a good source of minerals and vitamins (Table 3). Okiki *et al*. (2015) reported that *Moringa* leaf contains high levels of magnesium, zinc, potassium, calcium and phosphorus. In addition, it contains substantial levels of vitamins such as thiamine, ascorbic acid, niacin and riboflavin (Okiki *et al*., 2015).

Health Benefits of *Moringa:* *Moringa oleifera* is a tree associated with some health properties such as; antimicrobial, antioxidant, anti-inflammatory and anthelmintic properties. The potential health benefits of *Moringa* have been linked with potent phytochemicals such as; flavonoids, alkaloids, saponins, tannins, phenols and glycosides, which are major constituents present in *Moringa* (Malliga *et al*., 2014). The activities of these compounds have made the use of *Moringa* in folklore medicine popular in recent times. Basically, the prophylactic and therapeutic properties of *Moringa* have been documented by Fahey (2005), Patel *et al*. (2011), Makanjuola *et al*. (2014) and Allam *et al*. (2016).

Table 2: Amino Acid Profile of *Moringa oleifera* Leaf

Amino acids	Quantity in leaves (mg/g dry weight basis)
Lysine	15.30
Leucine	17.50
Isoleucine	8.90
Phenylalanine	8.90
Histidine	7.00
Threonine	7.90
Tyrosine	4.80
Valine	11.30
Methionine	1.40
Arginine	12.20
Proline	12.40
Glycine	10.30
Alanine	12.50
Serine	9.40
Glutamate	17.10
Asparatate	15.80

Source: Sánchez-Machado *et al*. (2010)

Table 3: Mineral and Vitamin Content of *Moringa oleifera* Leaf

Parameters	**Quantity**
Iron (mg/100g)	0.58
Zinc (mg/100g)	64.17
Magnesium (mg/100g)	643.33
Calcium (mg/100g)	82.50
Potassium (mg/100g)	430.00
Phosphate (mg/100g)	50.43
Ascorbic acid (mg/100g)	0.72
Thiamine (mg/100g)	0.22
Niacin (mg/100g)	1.48
Riboflavin (mg/100g)	1.48

Source: Okiki *et al*. (2015)

Antimicrobial Properties of *Moringa"* Extracts from the leaves and pods have been reported to have many health benefits and the seed extracts have been demonstrated to have antimicrobial properties (Atawodi *et al*., 2010). *In vitro* research studies carried out have established the antibacterial activities of *Moringa* leaf extracts (Patel *et al*., 2011; Vinoth *et al*., 2012). In another *in vitro* study conducted by Malliga *et al*. (2014), they confirmed the potent antibacterial properties of extracts from *Moringa oleifera* leaves against several gram positive and gram negative bacteria. Chollom *et al*. (2012) reported that the *Moringa oleifera* seed extract is not only nutritious but also possesses strong antiviral property and activity against Newcastle disease virus *in ovo*. The antibacterial property of the water extract of *Moringa oleifera* leaf stalk was reported by Thilza *et al*. (2010). The seed extracts of *Moringa oleifera* were observed to inhibit a broad spectrum of microbes (mostly gram positive bacteria) more than the leaf extracts (Rockwood *et al*., 2013). *Moringa oleifera* leaf meal is commonly considered as a plant protein feedstuff in animal nutrition and a potential antimicrobial agent for controlling pathogenic bacteria in livestock production (Atawodi *et al*., 2010; Makanjuola *et al*., 2014).

Antioxidant Properties of *Moringa:* The presence of high levels of polyphenols with antioxidant activity in *Moringa* leaves have been reported by Sreelatha and Padma (2009), Verma *et al*. (2009) and Moyo *et al*. (2012). Luquman *et al*. (2012) established from their research results the antioxidant activity of the aqueous and ethanolic extract of *Moringa* fruits and leaves, a pharmacological property that can be used in the field of medicine as a potent and natural antioxidant. The concentration of some antioxidants present in *Moringa oleifera* leaf extract include ascorbic acid 2.91mg/g $\pm$ 0.032, reduced glutathione 32.00nmoles/g $\pm$ 1.000 and total carotenoids 8.75mg/g $\pm$ 0.086 (Malliga *et al*., 2014). The antioxidant property of *Moringa oleifera* leaf extract was also documented in the research conducted by Allam *et al*. (2016). *Moringa* leaves and fruits contain both phenolic and non-phenolic bioactive constituents which function as an antioxidant by scavenging free radicals, terminating the reaction chain of free radicals and by converting them into a more stable compound (Faizi *et al*.,1994; Luquman *et al*., 2012).

Qwele *et al*. (2013) reported significant antioxidant effect in meat samples of goats fed *Moringa oleifera* leaf meal, these authors also suggested that dietary *Moringa* could be used as a beneficial means of protecting animals from diseases caused by oxidative stress and as well as improving meat quality. A similar observation was made earlier by Jung *et al*. (2010), they stated that feeding animals with plants containing antioxidants is a way of circulating and retaining the antioxidants in the tissue of the animal.

Anti-Inflammatory Activity of *Moringa oleifera:* Various parts of the *Moringa oleifera* plant, that is the leaves, roots and seeds have been reported to produce anti-inflammatory effect. Fayazuddin *et al*. (2013) posited that the aqueous and ethanolic extracts of *Moringa oleifera* seeds possess anti-inflammatory activity. This anti-inflammatory property may likely be due to the activity of bioactive compounds present in *Moringa oleifera* seeds. The inhibition of the production of pro-inflammatory cytokines by *Moringa oleifera* seeds may be linked to its anti-inflammatory action (Mahajan *et al*., 2007). Singh *et al*. (2012) posited

from the results obtained from their research studies that the anti-inflammatory action of the leaf extract of *Moringa oleifera* is likely due to its ability to inhibit the enzyme cyclooxygenase and as well as the inhibition of prostaglandin synthesis which is associated with inflammation. Mahajan *et al*. (2009) found that n-butanol extract of *Moringa oleifera* seeds exhibited anti-inflammatory effect against ovalbumin induced airway inflammation in guinea pigs. Conclusively, it has been reported that there are bioactive compounds with potent anti-inflammatory activity present in *Moringa oleifera* which is capable of suppressing the effect of inflammation (Farooq *et al*., 2012).

Anthelmintic Property of *Moringa oleifera:* The challenge of helminths developing resistance to synthetic anthelminthic drugs over time, its residual effect in meat and other animal products and its high cost for small scale livestock farmers have resulted in the search for natural and affordable alternatives. Research studies have demonstrated the anthelmintic activity of *Moringa oleifera* (Rastogi *et al*., 2009; Moyo *et al*., 2013). The use of *Moringa* as a natural anthelmintic will, therefore, reduce the over dependency on synthetic anthelmintic medicines and as well as encourage the production of organically produced healthy meat which is generally preferred by consumers.

According to Mbogning Tayo *et al*. (2014), leaf extracts of *Moringa oleifera* in an *in vitro* study showed potential ovicidal and larvicidal (anthelmintic) activities against *Haemonchus contortus* a blood-sucking abomasal helminth of small ruminants which globally is responsible for huge economic losses of small scale farmers. Srinivasa *et al*. (2011) reported that both chloroform extract and methanol extract of *Moringa oleifera* exhibited anthelmintic activity. However, the chloroform extract of *Moringa oleifera* showed more potency against *Pheretima posthuma* (adult Indian earthworm) than the methanol extract (Srinivasa *et al*., 2011). Moyo *et al*. (2013) reported that supplementing the diets of cross-breed Xhosa Lop eared goats with *Moringa oleifera* leaves suppressed the coccidian-oocyst and helminth load. This research further supports and demonstrates the anthelmintic property of *Moringa oleifera* which was earlier reported by Rastogi *et al*. (2009). The aqueous and ethanolic extracts of the seeds of *Moringa oleifera* contains potent bioactive compounds with anthelmintic properties against the eggs and third stage larvae of *Haemonchus contortus in vitro* (Cabardo and Portugaliza, 2017). There is, therefore, need for more research into the production of natural anthelmintics particularly from *Moringa oleifera* for future use for livestock.

The Use of *Moringa* in Agricultural Production: Various parts of the *Moringa* tree have been found useful in agricultural production such as animal production, crop production, agroforestry, aquaculture and food science (food processing and product development).

Animal Production: *Moringa oleifera* can be used to improve livestock production. *Moringa oleifera* is one of the plants that can be integrated with livestock production, a cheap protein source which can be used to improve feed quality as well enhancing the digestibility of other diets (Moreki and Gabanakgosi, 2014). Fresh leaves of *Moringa oleifera* are readily consumed by cattle, sheep, goat, pigs and rabbits, it has also been incorporated into rations of poultry and fish (Mulugeta and Fekadu, 2014). Research studies have established that dietary *Moringa* has resulted in the improvement of the productive performance of livestock animals.

There are several beneficial effects of feeding *Moringa oleifera* in livestock production, namely; improvement in milk quality and production (Sanchez *et al*., 2006; Basitan and Jacia 2013; Khalel *et al*., 2014; Kholif *et al*., 2015 ; Cohen-zindera *et al*., 2016), increase in weight gain (Aregheore, 2002; Sultana *et al*., 2015; Briones *et al*., 2017), better meat quality attributes (Wapi *et al*., 2013; Mukumbo *et al*., 2014; Moyo *et al*., 2014), improved haematological profile (Fadiyimu *et al*., 2010; Fayomi *et al*., 2014), better diet digestibility (Aregheore, 2002; Sanchez *et al*., 2006; Kholif *et al*., 2015), improved egg quality and production (Ebenebe *et al*., 2013; Briones *et al*., 2017), better feed efficiency (Mahmoud, 2013; Briones *et al*., 2017).

Crop Production: *Moringa* farmers have observed over time the use of *Moringa oleifera* in promoting the growth and vitality of other crops and the usefulness of spraying *Moringa* leaf extract on crops (Martin, 2015). Research studies have revealed that *Moringa* leaf spray has several advantages on crops. The spray produced increased growth of young plants that were firmer and more resistant to diseases and pests (Foidl *et al*., 2001). In addition, the crops on which *Moringa* spray was applied had a longer lifespan, heavier stems, roots and leaves, produced more and bigger fruit and increase in yield of 20 to 35 percentage (Foidl *et al*., 2001).

Agroforestry: Agroforestry involves the cultivation and management of tree in farmlands and surrounding landscapes. *Moringa* has great potential as an agroforestry tree and can play a significant role in sustainable economic development in many developing countries of the world. This multipurpose tree has been recommended for cultivation in rural areas prone to deforestation and

to help rural dwellers in developing their forest resource as well as meeting their nutritional and economic needs (Suthari and Prasad, 2016).

Smallholder farmers in Zimbabwe plant *Moringa oleifera* as one of the trees grown with crops. It is a very useful tree for traditional agroforestry among smallholder farmers because of its multiple benefits (Palada, 1996). In addition, the farmers used *Moringa* tree as an inter-crop in a multi-storey system, hedge or ornamental plant (Gadzirayi and Mupangwa, 2014).

Aquaculture: Akinwole (2014) documented that *Moringa oleifera* seed powder was found to be useful and effective as a coagulation aid for the removal of suspended solids in the treatment of fish culture waste-water. The incorporation of *Moringa* leaf in the diet of Tilapia fish (*Oreochromis mossambicus*) resulted in significant increase in weight gain and specific growth rate (Karpagam and Krishnaveni, 2014). Additionally, Egwui (2013) suggested the use of *Moringa* as an alternative source of protein in aquaculture feeds and advocated the need for further research on other aspects of the utilization of *Moringa oleifera* in aquaculture.

Food Processing and Product Development: The knowledge about the relationship between food, health and nutrition is of paramount importance globally, as well as the need to develop foods with functional ingredients from plant sources. Agriculturalists, food scientists and nutritionists encourage the cultivation, incorporation and consumption of plant sources like *Moringa oleifera* due to its multiple beneficial properties. Many studies have shown the potential use of different parts of *Moringa oleifera* in food applications (Babayeju *et al*., 2014; Abou-Zaid *et al*., 2014; Arise *et al*., 2014; Hekmat *et al*., 2015; Emilike *et al*., 2016; Salama *et al*., 2017).

Fombang and Saa (2016) reported the production of antioxidant rich tea from *Moringa oleifera* leaf powder. *Moringa* seed, leaf and flower have been utilized in the preparation of complementary weaning foods and as composite blends in baked products. Arise *et al*. (2014) used *Moringa oleifera* flower in preparing weaning food. Ogunsina *et al*. (2011) reported incorporating 10% of debittered *Moringa* seed flour in baking bread, which had higher levels of iron, protein and calcium content. In addition, these researchers recommended that up to 20% inclusion level of debittered *Moringa* seed can be effectively used in the preparation of acceptable cookies with improved nutritional quality. The use of *Moringa* as food fortificant is becoming popular, for instance in the preparation of cakes (Kolawole *et al*., 2013), bread (Ogunsina *et al*., 2011; Chinma *et al*., 2014), soup (Babayeju *et al*., 2014), fortifying cereal gruel (Abioye and Aka, 2015). Srinivasamurthy *et al*. (2017) reported the successful inclusion of 12% dried *Moringa oleifera* leaf powder in the production of muffins with better nutritional value and overall sensory acceptability.

CONCLUSION

Moringa is a special plant with multiple uses and benefits. It is a plant with good nutritional and medicinal value. It is worth noting that the presence of bioactive compounds in *Moringa* is responsible for some of its beneficial properties. It has also been found to be useful in various agricultural sector. One of the unique advantages of *Moringa* is that it can be produced with ease and can strive in low fertile soils or under relatively harsh conditions where other plants cannot withstand or strive well. Farmers and rural dwellers need to be encouraged to engage in extensive cultivation and use of *Moringa* plant particularly, in the developing countries of the world, because of its numerous benefits. There are wide aspects of research yet to be fully exploited by utilizing *Moringa* plant, which has the potentials to boost agricultural production, therefore, more research should be directed towards the use and application of *Moringa* in hydroponic farming, micro-livestock production and horticulture.

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PHYSICOCHEMICAL AND SENSORY PROPERTIES OF JAMS PRODUCED FROM FOUR MANGO VARIETIES IN BENUE STATE, NORTH CENTRAL NIGERIA

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ABSTRACT

ABSTRACT
The study investigated the physicochemical and sensory properties of jams prepared from four popular mango fruits varieties (Julie, Peter, Dabsha and Hindi) in Benue State. A commercial mango jam was used as control. The physicochemical and sensory properties of the mango jams were determined using standard methods. Results revealed that the total soluble solids, titratable acidity and pH of the jams differed significantly. Jams produced from the Julie, Peter, Dabsha, Hindi mango varieties had higher total soluble solids compared with the commercial jam. The ash, vitamin A and C content of the jams ranged from 0.13 to 0.34 mg/100 g, 89.10 to 129.90 µg/100g and 12.12 to 24.07 mg/100g, respectively. The vitamin A contents of the prepared jams were significantly higher than the commercial mango jam. The prepared jams also had higher sensory attributes compared to the commercial mango jam. However, Dabsha mango jam was the most acceptable among the prepared jams.

Key words: Mango jam, mango varieties, physicochemical and sensory properties

INTRODUCTION

Mango is a fleshy juicy stone fruit with a characteristic yellowish-red colour (Venkateswarlu and Reddy, 2014). Mango originated from the Indian subcontinent and reached East Africa by 10th Century. Mango belongs to the genus *Mangifera*, consisting of numerous tropical fruiting trees in the flowering plant family *Anacardiaceae* in the order of *Sapindales*. Mango (*Mangifera indica*)is one of the most important commercial fruit trees grown in over 90 tropics and subtropics countries (FAO, 2009). Mango has over 1000 varieties and of these, only 100 varieties with similar properties and peculiarity are traded and grown for consumption both in fresh and processed form worldwide (Bally *et al.*, 2011).

Mango is the most popular fruit in many countries among millions of people in the world and at the same time it occupies a prominent place among the best fruits of the world (Bally *et al.*, 2009) especially in the tropic where it is considered to be the choicest of all indigenous fruits. Mangoes are a highly nutritious fruits containing carbohydrates (16.20-17.18 g/100g), proteins (0.36-0.40% g/100g), fats (0.33-0.53g/100g), Ash (0.34-0.52g/100g). Vitamins A and C has been found prominent with values ranging from 54-58µg and 9.79-186.00mg/100g respectively (Maldonado *et al*., 2019; USDA, 2018). Significant amount vitamin B1 (0.01-0.04 mg/100g), vitamin B2 (0.02 – 0.07mg/100g) and phenolic compounds are also present (Maldonado *et al*., 2019). The diversity of mango is so huge not only because of their number and variety but the distinct taste and features. Mango is one of the most widely cultivated fruit and according to Sauco (2017) world mango production has increased considerably and constantly: $15{,}700\times10^3$ tons in 1990, $25{,}040\times10^3$ tons in 2000, $30{,}880\times10^3$ tons in 2006 and $42{,}140\times10^3$ tons in 2012. However, this increase in production has been accompanied by large postharvest losses of 45% worldwide which has been attributed to poor utilization and limited value addition. To increase the availability of this fruit throughout the year, the surplus production must be processed into a variety of value-added products (Gathambiri, 2009).
Mango crop requires very low investment once they grow making them an important cash crop. Mango is grown in many parts of the western and southwestern parts of Nigeria and with Benue State topping the list with exotic varieties (Olaniyan, 2004; Avav and Uza 2002). Mango is one of the second potential fruit crop produced in Benue state next to orange, the production of mangoes in Benue State has earned Nigeria its 8th position on the chart of mango producers in the world (Ubwa *et al*., 2014).

Gboko with five districts namely, Mbatyav, Mbatierev, Mbayion, Ipav and Yandev is popular in mango fruit production (Ajayi and Nyishir, 2006). The local Government originally had Mango production covering over 70% of the total acreage allotted for fruit production with varieties of mango found such as *opioro* (known as the German mango in Benue), *peter*, *hindi*, *Julie*, *dabsha*, others are *kerosene mango* (so called because of its characteristic kerosene like odour*)* and *broken* (Ajayi and Nyishir, 2006). Mangoes produced in Nigeria are consumed as fresh fruits while the rest (approximately 50%) are lost due to lack of

processing industries, inadequate facilities for storage and transportation thus exacerbating the problem of postharvest (Okoruwa, 2018). The potentials in mangoes has been underdeveloped because the food processing industry in Nigeria is in its infant stage, and production of horticultural crops is much less developed than the production of food grains in the country hence less utilization of the available fruits.

Processing is considered as improving the value of raw produce and an extension of storage life (Okoth *et al.,* 2013) and one of the alternatives and profitable methods of using mangoes would be in processing mango for jam production. Jam preparation is one of the ancient methods and it is the best suited technique for preservation of perishable fruits (Bekele *et al*., 2020). Jam is a semi solid food and the production involves the disruption of the fruit tissue followed by heating with added water and sugar to activate its pectin before being put into containers (Mohammad *et al*., 2017). Mango is one of the most cherished fruits, not only in flavor and taste (Hussain *et al.,* 2005) but also for its nutritional value therefore giving its jam a suitable/acceptable taste and flavor. Mango jam is and also a good source of vitamin A and C, rich in carbohydrates, minerals potassium, and phosphorus (WHO, 2003). The suitability of mango variety for jam production is generally screened on the basis of juiciness, wholesomeness and its availability all year round.

Several researchers (Muhammad *et al*., 2012; Abdelazim *et al*., 2010; Bekele *et al*., 2020; Muhammad, 2013) have reported on quality of some mango jams in some regions of the world and composite mango jam from mango, pineapple and pawpaw has also been evaluated (Ogunbande *et al*., 2013). However, information on the production process and physicochemical properties of these mango jam varieties in Benue state are not available. Therefore, this study explores production of mango jam towards value addition of these varieties of mango with reduction of the major problem of post-harvest losses especially during the glut season. Mango jam production from varieties of mango available in Benue state could present jams with distinct flavor as each variety has a unique flavor attributed to it. This information would be important to small scale entrepreneur/processor and as such providing possible employment for the teeming population.

METHODOLOGY

Source of materials and sample preparation: Mangoes varieties used for this study were *Julie, Peter, Dabsha* and *Hindi* mango. Orange fruits and sugar was procured from Gboko main market, Benue State. A commercial mango jam used as control was sourced from the Shoprite superstore in Nsukka town, Enugu State.

Extraction of pectin: Pectin used in this study was extracted from orange rind using the method described by Girma and Worku (2016). Matured oranges were properly washed and peeled and the pith was peeled off from the back and cut into narrow strips. 100 ml of lemon juice was added to the chopped pith and allowed to sit for 1h; 700 ml of distilled water was then added to the mixture of the pith and lemon juice and allowed to simmer for 10 mins. The mixture was poured into a strainer lined with cheesecloth and allowed to drain for 12h and the pectin was collected. Flow chart for pectin extraction is as shown in Figure 1.

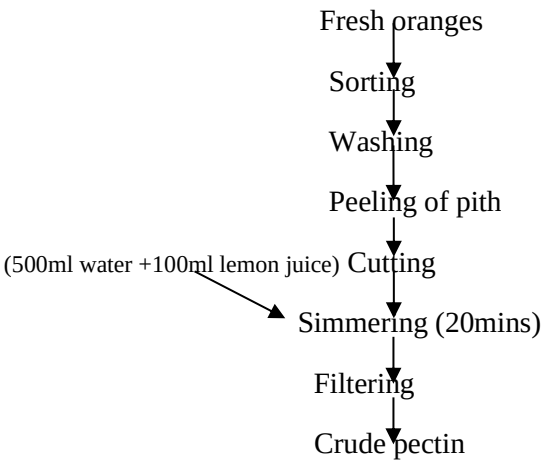

Figure 1: Extraction of pectin from orange pith
Source: Girma and Worku (2016)

P**ulp and jam yield determination:** Yield capacity was determined as the percentage pulp recovered after removal of skin and the seed from a weighed kilogram of mango fruits varieties.
Yield(%)= (pulp weight/Xg) x100 ……(1)
Xg= weight of whole mango fruit

Mango jam production: The method described by Bastin (2004) was adopted with slight modification by using seven hundred grams **(**700g) each of the matured and ripe selected varieties of mangoes. The mangoes were sorted, washed, peeled, and the core removed, the pulp was diced into smaller sizes followed by blending using a whirl blender (model) and boiled in 600ml distilled water for 10 min to soften the fruit pulp. Sugar (500 g) was added after 10min to the boiled pulp while mixing and 2 ml of the prepared pectin solution was added followed by the addition of 33g citric acid. The mixture was stirred continuously until a stable gel was formed and poured directly into an already sterilized jar and allowed to cool in cold water. The flow chart for the production of mango jams is as shown in Figure 2

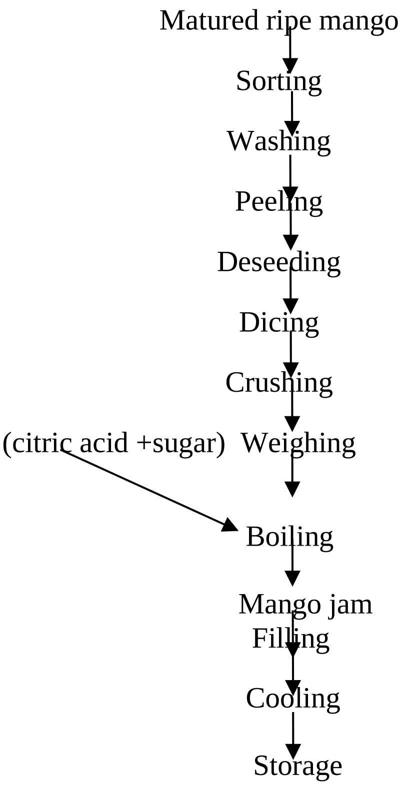

Figure 2: Production of mango jam
Source: Bastin (2004)

Determination of physicochemical properties
Determination of Total Soluble Solids (TSS), Total Titratable Acidity (TTA) and pH: Total soluble solids of the various mango jam sample determined using the Atago hand held Abbe refractometer (Rx 5000, Atago, Tokyo, Japan). The refractometer was maintained at 20 °C and calibrated with distilled water, this method is based on the principle that refractive index increases with increase in solid content. Two drops quantity of each sample was placed on the prism-plate of the refractometer and the reading appearing on the screen was directly recorded as total soluble solids (°Brix). Titratable acidity (TA) was determined according to the method described by AOAC (2012). Ten grams (10g) of the sample was weighed and diluted with 250ml of distilled water. 25ml of the diluents was taken and titrated with standardized solution of 0.1N Sodium hydroxide (NaOH) using 0.3 ml phenolphthalein as an indicator until a pink end point is attained which persists for about 30 seconds and the corresponding burette reading taken. The TA was calculated using the formula:

TA(%)= (ml of NaOH) × (N of NaoH) ×mil equivalent of A × 100/Weight of sample used ……………………………………………….(2).

The pH was determined using a glass electrode pH meter (Model; HANNA instruments 8521) at ambient temperature. Five grams (5g) of the various mango jam samples were weighed each into 10 ml of distilled water and allowed to stand for 30minutes in 40 °C water bath. The samples were removed and filtered using filter paper and the pH was determined. The pH meter was standardized and the pH was measured by inserting directly the electrodes into 10ml beaker containing the sample, the value was read from the pH meter to know the level of alkalinity or acidity of the mango jams products. The pH meter was rinsed immediately after use before proceeding to the next sample.

Determination of Ash, Minerals and Vitamins: Ash and vitamin C content of the various jam samples was determined using the method as described by AOAC (2012) and Vitamin A was analysed by determining the beta carotene content using the method described by Ranganna (1999) and the conversion factor by (FAO/WHO) was used to evaluate the Vitamin A content

Sensory evaluation: Sensory evaluation was carried out using the method as described by Iwe (2002). Twenty (20) trained sensory panelists consisting of students from the Department of Food Science and Technology, University of Mkar, Mkar Benue State. All evaluation sessions were held in the food sensory laboratory of the University. The mango jam samples from the various mango varieties were stored at 5°C and were taken out 2 h before serving. Appearance, flavor, mouth feel, degree of spread ability and overall acceptability sensory parameters of mango jam samples were evaluated using nine point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, 1 = dislike extremely). The panelists were briefed how to use sensory evaluation forms and terminologies of sensory attributes. All samples were presented in 50 ml cups coded with random, two-digit number to the panelists at room temperature under normal lightning conditions. Sliced bread pieces were used as carrier since jam is normally consumed with bread with spoons for scooping and spreading. Sensory Appearance, flavor, mouth feel, degree of spread ability, and overall acceptability Drinking water was provided for oral rinsing. The average values of the sensory scores were used in the analysis Mango jam was compared with a commercialized mango jam (Danish jam, made in Poland) as the reference jam.

Statistical Analysis: Data obtained were subjected to analysis of variance (ANOVA) and differences among means were compared using Duncan multiple range test at 5% probability level. All computations were made by statistical software SPSS (version 20).

RESULTS AND DISCUSSIONS

The pulp yield of the various mango samples is as presented in Table 1. The pulp yield ranged from 55.30 – 66.70% with *Dabsha Mango* yielded the highest while and *Hindi* the lowest. These variations could have been due to growing conditions and varietal difference as some of these varieties have larger seeds which may influence the percentage yield. High pulp ratio will be of economic benefit in the production of jam among other factors such as seed ratio, firmness, maturity and fibre absence (Pleguezuelo *et al.*, 2012). The pulp content of these mango varieties are slightly lower than the values reported by Bekele *et al*. (2020) on pulp contents of Ethiopians mangoes which ranged from 65.44-78.14% while it falls within the range of 62.01, 66.23 and 68.23 % reported by Ubwa *et al*. (2014) for *Julie*, *Hindi* and local mango pulps of Benue state respectively. The, total titrable acidity total soluble solids and pH of the various mango jam samples is as presented in Table 1.

Table 1: Pulp yield and the physicochemical properties of the various mango jam

Sample	Pulp yield (%)	TSS (brix^o)	TTA (%)	pH
SJ	ND	29.00^d±1.41	0.29^a±0.01	3.10^e±0.00
HMJ	60.78± 3.10	65.50^c±0.70	0.20^b±0.02	3.70^a±0.00
JMJ	62.30± 2.87	66.50^c±2.12	0.16^c±0.02	3.31^b±0.01
PMJ	64.80± 1.65	79.00^a±1.41	0.35^a±0.15	3.21^d±0.02
DMJ	66.70± 2.05	72.50^b±2.12	0.20^{bc}±0.01	3.40^c±0.02

Values with different superscript within same column are significantly (P≤0.05) different.
TSS= Total soluble solids , TTA= Total titratable acid , SJ=Commercial control, HMJ=*Hindi* mango jam JMJ=*Julie* mango jam, PMJ=*Peter* mango jam and DMJ=*Dabsha* mango jam

The TSS ranged from 29.00 to 79.00 brix^o with the control mango jam sample (SJ) having the lowest and sample while PMJ had the highest value. There was a significant ($p<0.05$) difference among the samples' TSS and all the mango jam produced had higher TSS than the control. High TSS in food products is a positive index of gelling (Ogunbande *et al*., 2013). TSS also indicates the possibility sweetness invariably sweeter jams were produced from the Benue mango varieties compared with the commercial jam (SJ). High sugar content is more advantageous as the moisture would not be available as free water. Sugar acts as preservative by binding with the free water**.** Also, the bound water may not readily available for microbial growth and this leads to prolonged shelf life of jams (Bekele *et al*., 2020). The TSS values falls within the range of 60-65% or greater recommended by Codex alimentarius for standard soluble solids of jams and marmalade (FAO, 1981).

The TTA which ranged from 0.16 to 0.35% for the various mango jam samples is an indicator of the amount of organic acids present in the mango jams sample. JMJ had the lowest of 0.16% while PMJ had the highest value of 0.35%. Acid facilitates release of trapped pectin inside the fruit cells during heating of fruit with sugar, the addition of lemon juice lowers the acidity of the jam mixture and the total acid in the jam is also influenced by the acidity of the pulp. TTA influences the microorganism growth and proliferation, also influences the sensory attributes, preservation of the products and overall final quality of jam. The variation in the TTA value may be due to the level or degree of maturity and ripening of the mango varieties (Bekele *et al*., 2020; Nelson, 2014). The data reported are within the range (0.35, 0.37 and 0.34%) reported by Mohammed (2013) on jams from mango varieties in Darfur region India and 0.23-0.83 % reported by Bekele *et al*. (2020) on some Ethiopian mango jams. The pH is the natural logarithm of the hydrogen ion concentration of a substance. It is an important factor to obtain optimum gel condition in jam making. Hydrogen ion influences the rates of growth of bacteria, yeasts and molds. The pH values ranged from 3.10 – 3.70 with the control (3.10) being more acidic than the other mango jam varieties. This could be attributed to variation in acidity of the mango pulps. This pH range compare favorably with the Ethiopian mango jams with pH ranging from 3.33 – 4.75 (Bekele *et al*., 2020). According to Kordylas (1990) and FAO (2009), standard jam pH recommendation ranges from 3.00-3.50. Therefore, all the mango jam samples fall within the range of standard jams except HMJ which shows a slightly higher value.

The ash, vitamin A and C content of the various mango jam samples is as presented in Table 2. Ash, Vitamins A and C result of the various mango jams is as presented in Table 2. Ash content of food materials gives an indication of the mineral composition of the food sample which is very important in the biochemical functions of the body. The ash content of the various mango jam samples ranged from 0.13 to 0. 34%, while the vitamin A and C ranged from 89.10 – 129.90 µg/100g and 12.12 – 24.07 mg/100g respectively. There was significant ($p<0.05$)

Table 2: Ash, vitamins A and C contents of jam produced from selected varieties of mango

Jam Samples	Ash (%)	Vitamin A (µg/100g)	Vitamin C (mg/100g)
SJ	0.13^{b}± 0.01	89.1^{c}±0.04	24.07^{a}±0.10
HMJ	0.34^{a}±0.02	89.3^{c}±0.08	16.10^{c}±0.14
JMJ	0.33^{a}±0.03	129.90^{a}±0.07	12.12^{d}±0.17
PMJ	0.30^{c}±0.02	102.8^{b}±0.02	18.15^{b}±0.21
DMJ	0.33^{a}±0.04	92.8^{d}±0.03	16.10^{c}±0.14

Values with different superscript within same column are significantly (P≤0.05) different.
SJ=Commercial control HMJ=*Hindi* mango jam, JMJ=*Julie* mango jam PMJ=*Peter* mango jam DMJ=*Dabsha* mango jam

difference among the mango jam samples vitamin contents. Vitamin A and C are dominant in mango fruits, USDA (2018) reported vitamin A and C content to be 92.8 and 39 -54µg respectively for whole mango fruits. Varietal differences could have played a role in the variations in the vitamin compositions and response to the heat process by the Vitamins. According to Onimawo and Akubor (2012) vitamin A is destroyed when heated in the presence of oxygen. Vitamin C content is also affected by the stage of ripening, it is higher in less ripe mango fruit compared with fully ripe mango (Matheyambath *et al*., 2016). These mango jams varieties can serve as source of micronutrient vitamin A (from beta carotene).

Sensory attributes of mango jam samples: The mean sensory scores for the various mango jams samples is as presented in Table 3. Mango jams produced from the local varieties were rated higher in appearance, flavor, mouthfeel spreadability, and were more acceptable than the commercial mango jam used as control. Appearance gives the visual assessment which is the first impression and a key feature in the choice of consumer for products preference, purchase and final use (Abid *et al*., 2018). The mean sensory score for appearance ranged from 5.55 – 8.45, while flavor which is a combination of taste and aroma ranged from 5.70 – 8.60 with the mango varieties having higher scores than the commercial mango jam. This could be as result of sweetness as detected in the TSS content values and also the distinctive aroma of these varieties of mangoes. Mean sensory scores for mouthfeel and spreadability ranged from 5.80 to 8.40 and 6.10 to 8.30 respectively with mango sample DMJ the most acceptable with the mean score of 8.70. DMJ was the most acceptable probably due of to its bright colour, distinctive flavor of the original fruit, intermediate consistency, and texture fulfilling the quality of a good jam (Rababah, 2014). All the mango jam samples were generally accepted at confidence limit of 5%.

CONCLUSION AND RECOMMENDATION

This study demonstrated that acceptable and standard mango jams can be produced from the *Dabsha*, *Hindi*, *Julie* and *Peter* mango varieties found in Benue State. All the mango varieties had an appreciable pulp yield and the total soluble content was higher than the commercial jam. Jams produced from these varieties were found to meet up with the standard jam requirements. Sensory evaluation rated the varieties of Benue mango jam higher than the commercial mango jam with *Dabsha* variety mango jam as the most acceptable. Further studies are recommended on the storage stability of the prepared mango jams.

Table 3: Mean sensory scores of jam produced from selected varieties of mango

Samples	Appearance	Flavor	Mouth feel	Spraedability	Overall Acceptability
SJ	5.55^{c}±1.03	5.70^{b}±1.41	5.80^{c}±1.23	6.10^{c}±1.25	6.60^{c}±0.75
HMJ	7.45^{b}±0.94	8.05^{a}±0.75	7.60^{b}±0.59	7.90^{ab}±0.91	8.05^{a}±0.75
JMJ	8.15^{a}±0.81	8.00^{a}±1.21	8.00^{ab}±1.21	8.15^{a}±0.87	8.40^{ab}±0.68
PMJ	8.20^{a}±0.77	8.05^{a}±0.94	7.85^{ab}±0.81	7.35^{b}±0.98	8.05^{b}±0.75
DMJ	8.45^{a}±0.76	8.60^{a}±0.59	8.40^{a}±0.68	8.30^{a}±0.80	8.70^{a}±0.47

Values with different superscript within same column are significantly (P≤0.05) different.
SJ=Commercial control, HMJ=Hindi mango jam, JMJ=Julie mango jam,
PMJ=Peter mango jam, DMJ=Dabsha mango jam

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EFFECTS OF BIOCHAR DERIVED FROM DIFFERENT FEEDSTOCK ON COWPEA PRODUCTIVITY IN MINNA, SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT
Evaluating the crop response to different biochar type could be a necessary step in adapting biochar technology into the current intensification of legume production in the savanna region of Nigeria. A pot experiment was conducted to evaluate the effect of biochar derived from different feedstocks on cowpea growth and nodulation, in Minna, Nigeria. The experiment was a 4 × 5 factorial experiment consisting of four (4) biochar types made from different feedstock at five (5) application rate and fitted into a completely randomized design (CRD) at three (3) replicates. The Four biochar types were; poultry manure, swine dung manure, sawdust and maize cob biochars and the five different application rates were; 0 tons ha^{-1}, 30 kg P ha^{-1}, 5 tons ha^{-1}, 10 tons ha^{-1}, and 15 tons ha^{-1}. The results showed that, applying biochar made from Poultry manure and Swine dung increased cowpea height and number of leaves compared to biochar made from sawdust and maize cob. Amending soil with biochar at the rate of 10 or 15 tons/ha led to taller plants and more numerous leaves similar to that of 30 kg P ha^{-1}, whereas, 0 tons/ha gave shorter plants with fewer leaves over the growing period. Application of biochar derived from poultry manure increased the Shoot, root, nodule, and total biomass, shoot/root ratio, root length, number and percentage of effective nodules compare to the other biochar types. Applying biochar at 15 tons/ha significantly increased all the above and below ground biomass similar to that of 30 kg P ha^{-1}. The significant interaction between biochar type and rate showed that application of biochar at rate up to 10 or 15 tons/ha of manure-based biochar could replace the use of 30 kg P ha^{-1}. This study has found that, biochar derived from animal manure have potential to improve cowpea growth and productivity at 10 tons/ha. There is need to re-examine this effect in a field study to validate this claim.

Key words: Cowpea, nodulation, biochar, feedstock, Soil Amendment.

INTRODUCTION

Cowpea (*Vigna unguiculata L Walp*) which comes from the family *fabaceae* and is a native to Africa. It is one of the most important crops grown in the arid and semi- arid regions of the tropics covering Asia, Africa, Southern Europe, and Central America (Xu *et al.,* 2016). In today's world, man's need for protein makes cowpea an irresistible option for food as cowpea provides a cheap source of human dietary protein especially in developing counties (Xu *et al.*, 2016). It also produces a large biomass used in agriculture either as feed for animals or incorporated into soil to enhance soil fertility. Growing cowpea in the rural area is also beneficial among rural farmers due to its ability to fix atmospheric nitrogen into the soil through a process called biological nitrogen fixation (BNF).

Through biological nitrogen fixation nitrogen gas (N_2) present in the atmosphere is fixed and turned into readily available nitrogen for the preceding plant's uptake with the aid of soil micro-organism like rhizobia. This process is fostered by a symbiotic relationship between microorganism and the plant root. Nodules are produced on the root which helps fix atmospheric nitrogen into the soil and in turn the plant provides carbohydrates for the microorganisms. These nodules become home for the bacteria. Usually this process happens only after the plant has grown to a certain stage but before it reaches that stage it has to also take up nutrient from soil. Problem of low soil fertility, and extreme soil acidity have being identified among many other to impede symbiotic relationship between legumes and microbes (Afolabi *et al*, 2014), affirming the need for a favorable environmental condition (Adekanmbi *et al*., 2019) to realize the success of BNF.

Soil amendments (inorganic and organic) are known to improve the uptake of nutrients, increase soil fertility, improve soil quality, and consequently increase crop growth and yield. Biochar has been identified globally for its use as an organic soil amendment which helps in the enhancement of soil fertility, crop growth, water retention and movement in the soil and in soil pollution control (Novotny *et al.*, 2015). Some other benefits of biochar are in raising the pH of the soil, attracting more useful microorganisms, improving the cation exchange capacity (CEC) and also acts as nutrient reservoir (Lehmann and Joseph 2009; Obia *et al.*, 2015).

Biochar is a smooth and fine grain charcoal which has very high but stable organic carbon content. It is made through the heating of natural feedstocks in the presence of limited oxygen or by pyrolysis and it is used today worldwide as soil amendment (Egambiedieva *et al.*, 2016). Naturally, it contains all trace elements that were originally contained in the pyrolysed biomass (Lehman and Rondon 2006). Biochar is made from different feedstocks ranging

from Animal waste, poultry litters down to wooden materials like shaving, and plant residue (e.g. straws, leaves, nuts, hulls, shells). There is a key difference between biochar made from different feedstock as some still retains some of their nutrients. Animal derived biochar are chemically distinct from other biochar (wood, crop residue) because of the high nutrient content and are similar to the conventional fertilizer (Filberto and Guant, 2013) in effect.

Due to the rapid population growth of Nigerians' and the need to increase agricultural productivity, food security and sustainability, increased agricultural practices has resulted in repeated harvest which slowly leads to rapid nutrient depletion, soil erosion, limited organic matter; soil degradation, limited agricultural land and low cation exchange capacity (CEC) (Bot and Benites, 2005). Inorganic fertilizer has been the major soil amendment used since the dawn of industrial age. However, Inorganic fertilizer has its limitations on microorganisms when applied in ignorance, sometimes resulting in leaching and encourages depletion of good and natural soils in the long run (Odesola and Owoseni 2010). It may exert adverse effect to the environment by contributing to the greenhouse gas emission (Saxena *et al.,* 2013). Organic manure is also used as amendment of soil to increase soil productivity, plant productivity and help in water retention and enhancement of microbial activity. However, the benefits of applying Organic manure is often short-lived due to faster decomposition owing to the prevailing tropical conditions.

Biochar is relatively cheap because it is processed from feedstocks and waste products that are locally sourced. This amendment used for improving soil properties and the subsequent crop growth, provides potential for carbon storage strategy in the soil and sequester carbon which in turn reduces global warming (Hunt *et al.,* 2010). Biochar characteristics vary due to variation in feedstocks and there is limited understanding of which biochar type and rate is most effective on cowpea growth and nodulation characteristics. Evidence exist that biochar application could significantly enhance legume growth, nodulation, symbiotic performance with beneficial soil microorganisms and enzyme activities (Egamberdieva *et al*., 2019). This is possible because biochar usually promotes favourable condition for microbial proliferation (Egamberdieva *et al.,* 2016). There may be a synergistic effect of applying biochar to soil as it may enhance the activity of the native rhizobia population and consequently enhance cowpea nodulation and nitrogen fixation. The aim of this study is to examine the effects of biochar derived from different feedstock (swine dung, poultry manure, sawdust, maize cob) on cowpea productivity in Minna, southern Guinea savanna of Nigeria.

METHODOLOGY

Study site : The soil used for the experiment was collected from the Teaching and Research Farm, School of Agriculture and Agricultural Technology, Federal University of Technology, Gidan-Kwano Minna (latitude 9˚31' 2.736" N, longitude 6˚2622. 548" E, altitude l89.60 m above sea level).The pot experiment was carried out at the school' horticultural garden (latitude 9˚ 31' 48.762" N, longitude 6˚27' 0.594" E, altitude 262.40 m above sea level). Minna is located in the southern guinea savanna of Nigeria. It has a mean annual rainfall of l248mm and a sub humid climate. It is also characterized by a dry season of about 5 months occurring from November to March and also has its mean maximum temperature of 33.5℃ from March to June (Ojanuga, 2006). Some of the physical characteristics of Minna area are the presence of gently undulating high plains which is developed on the basement of complex rocks made up of granites, migmatites, gneisses and schists , inselbergs of " older granite" and also low hills of schists which rises conspicuously above the plains beneath the plains bedrock and is deeply weathered. This constitutes the major part of the parent material (saprolites) (Ojanuga 2006).

Collection and preparation of soil sample : The soil sample was collected from a depth of 0 - 15cm within an area of lm by 2m. A shovel was used in the collection of the soil after which the soil was mixed thoroughly, air dried and passed through a 2mm sieve to remove stones and gravels from the soil. Samples for pre - planting analysis were taken from the collected bulk soil. The collected soil was transferred to the horticultural garden. The quantity of soil per pot used was 2.5 kg of soil

Treatment and experimental design : The experiment was a 4 x 5 factorial experiment which consisted of four biochar types and 5 rates fitted into a completely randomized design (CRD) with three replicates. The four biochar types used were swine dung biochar, poultry manure biochar, sawdust biochar, maize cob biochar. The biochar rates used were 0 tons ha^{-l}, 30 kg P ha^{-1}, 5 tons ha^{-l},10 tons ha^{-l}, 15 tons ha^{-l}.

Procurement of seeds and biochar : The variety of cowpea seed used for the experiment was IT99K-573-1-1 and this was sourced from the International Institute of Tropical Agriculture (IITA) Ibadan, while the biochar used were sourced from Bowen University Iwo, Nigeria. These biochar were characterized at Federal University of Technology Minna, Niger State following the same method used in soil analysis. The chemical properties of biochar derived from different feedstocks are shown on Appendix 1

Laboratory analysis of the soil : The physical and chemical properties of the sieved soil were analysed in accordance to the standard method described by IITA (1982). Particle size of soil was determined using the hydrometer method. Soil pH was measured in 1:2.5 soil/water and 0.01M $CaCl_2$ suspension with a pH meter. Organic carbon was determined by the Walkey- Black wet oxidation method. The available phosphorous was determined colometrically after Bray-Pl extraction. The exchangeable bases were extracted with a neutral 1N NH_4OAC solution. Na^+ and K^+ in the leachate were determined by flame photometry while Ca^{2+} and Mg^{2+} were determined by Na-EDTA titration. The exchangeable acidity was extracted by 1.0 N KCl. Effective cation exchange capacity was obtained by the summation of exchangeable cations and the exchangeable acidity. Total nitrogen was determined by micro Kjeldahl method.

Agronomic practice : The site where the pots were arranged was cleared manually using hoes to remove grasses and stumps. Jute bags were laid on the ground and polypots were placed on them. The air-dried soil was weighed and mix thoroughly with different biochar types and at different rates i.e. 5, 10, 15 tons ha^{-1} and three replicates was transferred into well plugged polypots. Water was added at 40% water holding capacity (WHC) and left to equilibrate for three days. Control pots i.e. 0 tons per hectare was also treated as pots with biochar while in pots for single super phosphate i.e. 30kg P ha^{-1}, the mineral fertilizer was dissolved with water and applied at the same time and rate applied to others. Sowing was carried out immediately after equilibration. Planting stick was used to make a hole in each pot at a depth of 2.5cm and 3 seeds were planted per poly pot. After one week of emergence, thinning was done plants were thinned to one plant per pot.

Measurement of growth and nodulation characteristics: Plant heights (cm) were measured using a tape rule at 4, 6 and 8 weeks after sowing (WAS) from all the pots during the growth period. Leaves were counted alongside the plant heights at 4, 6 and 8 (WAS) and the values were recorded for each biochar type and rate. After 8 weeks of planting, plants were harvested using a sharp scissor to cut the shoot from the plant base. The roots (contained in an intact ball of earth) were immediately washed in a 2mm sieve using water to remove soil and also to prevent detached nodules from entering into the water. Nodules were separated from the roots for counting. Shoot weight in grams (g) was immediately measured after harvesting and was also taken after drying in an oven regulated at 75°C to a constant weight for 48 hours. The weight was measured using an electronic weighing balance. The root length (cm) was obtain by measuring the root length using metre rule for each individual biochar type and rate. Root weight (g) was measured by recording an oven-dried weight after drying in an oven regulated at 75°C to a constant weight for 48 hours using an electronic weighing balance. Nodule number was obtained, and Nodules were oven-dried at 75°C to a constant weight after 48 hours to obtain the nodule dry weight as in shoot and root measurements. Prior to drying, the percentage effectivity of the nodules was checked after counting by selecting 5 nodules at random and was cut using a sharp razor blade. Those with pink to reddish-brown colour were recorded as effective while those with green or dark colour were ineffective. The percentage effective number of nodules were recorded.

Statistical analysis : All data collected were subjected to Analysis of Variance (ANOVA) using Minitab 17.0 version. Where mean differences are observed, Fishers pairwise comparism was used to separate the means at 5% level of significance.

RESULTS AND DISCUSSION

The physical and chemical properties of the soil used for the experiment was shown on Table 1. The soil was loamy sand. The soil pH was slightly acidic. The organic carbon (2.72 g kg^{-1}) and total nitrogen (0.003 g kg^{-1}) were low. The calcium (3.34 cmol kg^{-1}) and potassium (0.33 cmol kg^{-1}) contents were low. The available phosphorus (12 mg kg^{-1}) and magnesium (2.33 cmol kg^{-1}) contents were moderately available.

The main effects of biochar type and rate on plant height and number of leaves of cowpea at 4, 6 and 8 WAS were shown on Table 2. The application of the different biochar types showed significant effect ($P< 0.05$) on the plant height of cowpea at 4, 6 and 8 WAS. Poultry manure biochar and swine dung biochar produced taller plants compared to sawdust biochar and maize cob biochar at 4, 6 and 8 WAS (Table 2). There was no significant difference ($P>0.05$) between the biochar rates on cowpea plant height at 4 WAS. Application of 10 and 15 tons ha^{-1} produced statistically taller plants at 6 and 8 WAS compared to the control.

The application of the different biochar types had significant effect ($P< 0.05$) on the number of leaves of cowpea. Poultry manure biochar produced the highest number of leaves which was significantly different ($P<0.05$) from sawdust and maize cob biochar at 6 and 8 WAS (Table 2). Application of 10 and 15 tons ha^{-1} produced higher number of leaves which is significantly different from 0 and 5 ton ha^{-1} at 4 and 6 WAS but similar to 30kg P ha^{-1} at 4 WAS (Table 2).

The interaction effect of both biochar types and rates on the height of cowpea at 6 and 8 WAS were shown on Table 3 and the interaction effect of both biochar

types and rates on the number of leaves of cowpea at 4, 6 and 8 WAS were shown on Table 4.

The interaction effect of biochar types and rates on the number of leaves at 4 WAS revealed that 10 tons ha^{-1} of poultry manure biochar produced the highest number of leaves compared to other treatments, similar results was observed at 6 WAS. The result was similar to poultry manure biochar at 15 tons ha^{-1}. Poultry manure biochar applied 15 tons ha^{-1} produced the highest number of leaves than other biochar types and rates.

There was significant effect ($P < 0.05$) of biochar types on the shoot weight of cowpea with biochar made from poultry manure having the highest shoot weight, root weight and total biomass. Swine dung biochar was significantly difference from other sources of biochar applied (Table 5). The animal derived biochars (Poultry manure and Swine) were significantly higher than the plant-derived (maize cobs and sawdust) biochars in terms of shoot/root ratio, root length and number of nodules of cowpea. Application of 15 tons ha^{-1} had significant difference ($p< 0.05$) than other rates of biochar and 30 kg P ha^{-1}(Table 5).

The interaction effect between biochar types and rates on the shoot weight of cowpea revealed that the effect of poultry manure biochar at 10 and 15 tons ha^{-1} produced the highest shoot weight while the lowest shoot weight was observed at application of maize cobs biochar at 0 tons ha^{-1} (Table 6).

The interaction effect between biochar types and rates on the root weight of cowpea revealed that the effect of poultry manure biochar applied at 10 and 15 tons ha^{-1} produced the highest root weight which was significantly difference from other treatments. A similar result was observed on root length (Table 7).

The interaction effect between biochar types and rates on the number of nodules of cowpea revealed that the effect of poultry biochar applied at 5 tons ha^{-1} and swine dung at 15 tons ha^{-1} produced the highest nodule number which was significantly different from other treatments (Table 8). The interaction effect between biochar types and rates on the weight of nodules was shown in Table 8. Application of poultry manure at 15 tons ha^{-1} produced the heavier nodule weight which was similar to 10 tons ha^{-1} while the lightest was observed when sawdust and maize cobs were applied at 0, 5 and 10 tons ha^{-1} (Table 8).

Biochar has been reported to generally improve the biomass of leguminous crops at all stages of growth (Lehmann and Joseph, 2009). Results from this study have shown that, poultry manure followed by swine dung biochar produced taller cowpea plants and numerous leaves, but maize cob biochar and sawdust biochar consistently produced shorter plants and fewer leaves. This may be due to the difference in the chemical composition of the individual feedstock (Filberto and Guant 2013). Filberto and Guant (2013) also reported that animal derived biochar produced higher amount of calcium, potassium, nitrogen and phosphorous which sometimes may be similar to conventional fertilizer. Biochar feedstock derived from animal manure greatly influences the height and number of leaves of cowpea and this may be due to increase availability of nutrients for plant uptake. Application of 30 kg P ha^{-1} also produced tall cowpea plants with reasonable number of leaves but not as much as 10 and 15 tons biochar ha^{-1} which indicates that cowpea is a phosphorous loving crop and application of biochar at 10 or 15 tons could replace the inorganic P requirement of cowpea. Biochar have previously been praised for its ability to increase nutrient more than inorganic fertilizer (Lehmann and Joseph 2009, Adekiya *et al.*, 2020). The chemical nature of the feedstocks of biochar made from poultry manure increases the soil pH because of its alkaline nature, hence it provides a favourable environment for cation exchange. Although maize cob biochar was also alkaline in nature, the chemical nature of the feedstock may be responsible for its poor output even when it was applied at 10 and 15 tons ha^{-1} (Lehmann and Joseph, 2009).

The highest positive effects were observed at the application of poultry manure biochar on the shoot weight, root weight, root length, shoot-root ratio, total biomass, number of nodules, nodule weight and effectivity. There was a partitioning effect that favours the above rather than below ground biomass when Swine dung biochar and poultry manure biochar were added to the soil and this was better represented by the shoot-root ratio. This effect is logical in terms of crop growth since good biomass accumulation is required to achieve better yield. Animal derived biochars also produced the longest roots and the highest number of nodules of cowpea. This may be due to the individual nature of feedstocks and higher nutrient content of biochar made from Poultry manure and Swine dung(Animal derived biochars) as biochar made from Animal wastes contains high minerals like calcium, phosphorous and total nitrogen, this could enhance the growth of roots and better ability to forage for more nutrients and moisture and also produce nodules for BNF (Filberto and Guant, 2013). Agboola and Moses, (2015), noted that, although addition of biochar significantly affects the root length, shoot weight, root weight, nodule number, weight and effectivity in legumes, biochar types significantly affect ability of biochar to enhance legumes growth.

The application 30 kg P ha^{-1} which serves as fertilizer control in this study produced the longest roots and highest percentage effective nodules. This indicates that phosphorous is very important in the development and infestation of cowpea root by

native rhizobia. But a similar effect was observed with the application of 15 tons biochar ha^{-1}. This may mean that biochar applied at l5 tons ha^{-1} can substitute for the application of 30 kg P SSP ha-1 which was the major fertilizer requirement of cowpea in the area. An application of 10 and 15 tons biochar ha^{-1} had similar effects on shoot-root ratio, nodule weight, number and root weight which also showed higher positive effect. These effects may be due to the formation of more effective nodules as pH improves. This implies that legume growth may benefit from biochar addition to enhance the biochemistry of the soil environments which may influence the root length, shoot weight, root weight, nodule number, weight and effectivity. It is also evidenced that the ability of biochar to enhance legumes growth is significantly by the biochar rates as biochar applied below 10 tons ha^{-1} did not support growth appriopriately. Poultry manure biochar applied at both 10 tons and 15 tons ha^{-1} produced the highest effects on shoot weight, total biomass and root weight in this study while it was noted that poultry manure biochar applied at 15 tons ha^{-1} produced the highest effect on nodule weight. This may be due to the increasing availability of nutrient by biochar. Poultry manure biochar applied at 10 and 15 tons ha^{-1} produced similar root length with those of 30 kg P ha^{-1}. This indicates that, though cowpea is a phosphorous loving crop, an application of poultry manure biochar at 10 and 15 tons ha^{-1} can directly substitute for the application of 30 kg P ha^{-1}. Our result then implied that that, biochar made from animal derived feedstocks, when applied in the appropriate quantity can increase the availability of nutrient present for plant uptake.

CONCLUSION AND RECOMMENDATION

In conclusion, poultry manure biochar produced the most outstanding effects on the overall growth and nodulation characteristics of cowpea while biochar applied at 10 tons and 15 tons ha^{-1} had the most positive influence on the overall growth of cowpea. This result was at par with the effect of Swine biochar and they are comparable to application of inorganic P fertilizer at 30 kg P ha^{-1}. There is however an urgent need to conduct further studies to access the effect of animal derived biochar applied at 10 tons ha^{-1} on the production of cowpea under field conditions to validate this view.

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Table 1: Some Physical and Chemical Properties of the Soil used for the experiment

Parameters	Values
Sand (g kg^{-1})	809.4
Silt (g kg^{-1})	56.4
Clay (g kg^{-1})	104.2
Textural class	Loamy sand
pH in water at 1: 2.5	6.2
pH in $CaCl_2$ at 1: 2.5	5.83
Organic Carbon (g kg^{-1})	2.72
Total Nitrogen (g kg^{-1})	0.003
Available phosphorus(mg kg^{-1})	12
Exchangeable Bases (cmol kg^{-1})	
Ca^{2+}	3.34
Mg^{2+}	2.33
Na^{+}	0.68
K^{+}	0.33
Exchangeable acidity (cmol kg^{-1})	0.022
Effective Cation Exchange Capacity cmol kg^{-1}	6.7

Table 2: Effects of Biochar Type and Rate on plant height and number of leaves of cowpea

	Plant heights (cm $plant^{-1}$)			Number of leaves ($plant^{-1}$)		
Treatments (T, WAS)	4	6	8	4	6	8
Biochar Type						
Swine dung	23.17^{ab}	21.96^{a}	27.19^{a}	8^{b}	11^{a}	13^{a}
Poultry manure	24.48^{a}	23.38^{a}	30.26^{a}	10^{a}	13^{a}	14^{a}
Sawdust	20.25^{c}	18.3^{b}	18.81^{b}	7^{b}	8^{b}	9^{b}
Maize cob	21.87^{bc}	18.34^{b}	19.17^{b}	7^{b}	8^{b}	9^{b}
SE±	0.73	0.77	1.51	0.5	1	1
level of significance	S	S	S	S	S	S
Biochar Rates / ha (R)						
0 tons	20.84^{a}	16.23^{b}	15.48^{c}	6^{c}	5^{c}	6^{b}
30 kg P	23.3^{a}	21.68^{a}	24.98^{ab}	9^{a}	11^{ab}	13^{a}
5 tons	22.48^{a}	19.96^{a}	22.34^{b}	7^{b}	9^{b}	12^{a}

10 tons	23.08[a]	22.29[a]	28.44[a]	9[a]	13[a]	13
15 tons	22.86[a]	22.32[a]	28.04[a]	9[a]	14[a]	14[a]
SE±	0.82	0.86	1.69	0.5	1	1
level of significance	NS	S	S	S	S	S
T×R	NS	S	S	S	S	S

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison
S= Significance at P<0.05 ; NS= Not Significant at P> 0.05

Table 3 : Interaction between Biochar type and rate on plant height of cowpea at 6 and 8 WAS

Biochar types	Biochar rates (ha^{-1})				
	0 tons	30 kg P	5 tons	10 tons	15 tons
			6 WAS		
Swine dung biochar	16.8[fgh]	22.93[bcde]	21.67[cdef]	23.73[bcd]	24.67[bc]
Poultry biochar	15.87[gh]	20.53[cdefg]	23.23[bcd]	29.63[a]	27.63[ab]
Sawdust biochar	17.6[fgh]	21.63[cdef]	18.13[efgh]	16.43[gh]	17.7[fgh]
Maize cob biochar	14.67[h]	21.6[cdef]	16.8[fgh]	19.37[defgh]	19.27[defgh]
			8 WAS		
Swine dung biochar	16.83[gh]	29.17[bcdef]	24[cdefg]	32.27[bcd]	33.7[bc]
Poultry biochar	13.8[h]	24.53[cdefg]	31.37[bcde]	43.53[a]	38.07[ab]
Sawdust biochar	17.53[gh]	22.07[efgh]	17.27[gh]	17.97[gh]	19.2[gh]
Maize cob biochar	13.77[h]	24.17[cdefg]	16.73[gh]	20[fgh]	21.2[fgh]

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparism

Table 4: Interaction between Biochar type and rate on the number of leaves of cowpea at 4, 6 and 8 WAS

	Biochar types		Biochar rates (ha^{-1})		
	0 tons	30 kg P	5 tons	10 tons	15 tons
			4 WAS		
Swine dung biochar	6[ghi]	7[fghi]	7[fghi]	10[bcd]	9[bcdef]
Poultry biochar	5[hi]	8[cdefg]	10[bcde]	15[a]	12[b]
Sawdust biochar	6[ghi]	11[bc]	6[ghi]	5[i]	7[fghi]
Maize cob biochar	6[ghi]	8[defgh]	6[ghi]	7[fghi]	7[fghi]
			6 WAS		
Swine dung biochar	6[def]	12[bc]	13[b]	13[bc]	13[b]
Poultry biochar	4[ef]	9[bcdef]	10[bcd]	20[a]	25[a]
Sawdust biochar	6[def]	12[bc]	6[def]	7[cdef]	8[bcdef]
Maize cob biochar	3[f]	12[bc]	6[def]	11[bcd]	9[bcde]
			8 WAS		
Swine dung biochar	7[ghij]	13[cdef]	15[bcd]	12[cdefg]	16[abc]
Poultry biochar	5[ij]	11[cdefgh]	19[ab]	15[bcd]	21[a]
Sawdust biochar	6[hij]	13[cdef]	8[efghij]	12[cdefg]	9[efghij]
Maize cob biochar	4[j]	13[cde]	8[efghij]	12[cdefg]	10[defghi]

Means that do not share a letter are significantly different at P< 0.05 using Fisher pairwise comparison

Table 5 : Effects of Biochar Type and Rate on above and below ground cowpea productivity and Nodule characteristics

Treatment	Shoot weight (g plant-1)	Root weight (g plant-1)	Total Biomass (g plant-1)	Shoot/Root ratio (plant-1)	Root length (cm plant-1)	Number of Nodules (plant-1)	Nodule weight (g plant-1)	Nodule effectivity (%)
Biochar Type (T)								
Swine dung	1.63[b]	1.11[b]	2.73[b]	1.44[a]	26.45[a]	16[a]	0.07[b]	66.67[b]
Poultry manure	2.42[a]	1.65[a]	4.07[a]	1.34[a]	26.51[a]	18[a]	0.14[a]	73.33[a]
Sawdust	0.47[c]	0.56[c]	1.02[c]	0.8[b]	26.8[a]	6[b]	0.02[c]	54[ab]
Maize cob	0.54[c]	0.69[c]	1.23[c]	0.75[b]	22.12[b]	6[b]	0.02[c]	40[b]
SE±	0.18	0.1	0.23	0.15	0.99	2	0.01	7.87
level of significance	S	S	S	S	S	S	S	S
Biochar Rates / ha (R)								
0 tons	0.17[c]	0.31[b]	0.48[d]	0.71[a]	18.27[d]	1[b]	0.0007[b]	13.33[c]

30 kg P	1.19^{b}	1.17^{a}	2.35^{bc}	1.03^{a}	31.76^{a}	15^{a}	0.07^{a}	88.33^{a}
5 tons	1.21^{b}	1.01^{a}	2.22^{c}	1.17^{a}	21.92^{c}	12^{a}	0.07^{a}	61.67^{b}
10 tons	1.76^{ab}	1.24^{a}	3^{b}	1.16^{a}	26.76^{b}	14^{a}	0.08^{a}	56.67b
15 tons	2^{a}	1.28^{a}	3.28^{a}	1.35^{a}	28.64^{ab}	16^{a}	0.09^{a}	72.5^{ab}
SE±	0.2	0.11	0.25	0.17	1.1	2	0.01	8.8
level of significance	S	S	S	NS	S	S	S	S
T×R	S	S	S	NS	S	S	S	NS

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison
S= Significance at P<0.05 ; NS= Not Significant at P> 0.05

Table 6. Interaction effect between biochar types and rates on the shoot weight and the total biomass

	Biochar types		Biochar rates (ha^{-1})		
	0 tons	30 kg P	5 tons	10 tons	15 tons
			Shoot weight (g plant^{-l})		
Swine dung biochar	0.23^{ef}	1.37^{cde}	1.92^{bcd}	2.03^{bcd}	2.59^{b}
Poultry biochar	0.13^{f}	1.16^{def}	2.33^{bc}	4.06^{a}	4.43^{a}
Sawdust biochar	0.21^{ef}	1.34^{def}	0.35^{ef}	0.27^{ef}	0.37^{ef}
Maize cob biochar	0.12^{f}	1.08^{ef}	0.22^{ef}	0.66^{ef}	0.59^{ef}
			Total biomass (g plant^{-l})		
Swine dung biochar	0.73^{f}	2.34^{cd}	3.12^{bc}	3.46^{bc}	4.01^{b}
Poultry biochar	0.3^{f}	2.51^{cd}	4.35^{b}	6.3^{a}	6.9^{a}
Sawdust biochar	0.51^{f}	2.27^{cde}	0.77^{f}	0.72^{f}	0.84^{ef}
Maize cob biochar	0.35^{f}	2.28^{cd}	0.63^{f}	1.52^{def}	1.35^{def}

Means with the same letter in a column within the same treatments are not significantly different (p>0.05)

Table 7. Interaction between Biochar type and rate on the Root length and Root weight

Biochar types	Biochar rates (ha^{-1})				
	0 tons	30 kg P	5 tons	10 tons	15 tons
			Root length (cm plant^{-1})		
Swine dung biochar	26.17^{cde}	28.77^{abcde}	23.7^{e}	27.23^{cde}	26.37^{cde}
Poultry biochar	13.83^{f}	34.27^{a}	25.47^{cde}	28.17^{abcde}	30.83^{abc}
Sawdust biochar	23.57^{e}	33.87^{ab}	24.67^{cde}	24de	27.9^{bcde}
Maize cob biochar	9.5^{f}	30.13^{abcd}	13.87^{f}	27.63^{bcde}	29.47^{abcde}
			Root weight (g plant^{-1})		
Swine dung biochar	0.51^{efg}	0.97^{cde}	1.2^{cd}	1.43^{bc}	1.42^{bc}
Poultry biochar	0.18^{g}	1.35^{cd}	2.02^{ab}	2.24^{a}	2.47^{a}
Sawdust biochar	0.3^{fg}	1.14^{cd}	0.42^{efg}	0.45^{efg}	0.47^{efg}
Maize cob biochar	0.23^{g}	1.2^{cd}	0.41^{efg}	0.86^{cdef}	0.76^{defg}

Means that do not share a letter are significantly different at P < 0.05 using Fisher pairwise comparison

Table 8 : Interaction between Biochar type and rate on the Number of nodules and Nodule weight of cowpea

Biochar types	Biochar rates (ton ha^{-1})				
	0	30 kg P	5	10	15
			Number of nodules (No. plant^{-1})		
Swine dung biochar	0^{f}	17^{abc}	15^{bcd}	22^{ab}	26^{a}
Poultry biochar	0^{f}	16^{abcd}	26^{a}	23^{ab}	25^{ab}
Sawdust biochar	4^{ef}	11^{cde}	5^{def}	3^{ef}	7^{cdef}
Maize cob biochar	0^{f}	15^{bcd}	1^{ef}	7^{def}	6^{def}
			Nodule weight (g plant^{-1})		
Swine dung biochar	0^{f}	0.08^{de}	0.09^{d}	0.1^{cd}	0.1^{d}
Poultry biochar	0^{f}	0.08^{de}	0.16^{bc}	0.18^{b}	0.25^{a}
Sawdust biochar	0^{f}	0.08^{de}	0.02^{ef}	0^{f}	0.01^{f}
Maize cob biochar	0^{f}	0.05^{def}	0^{f}	0.02^{f}	0.01^{f}

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison

Appendix 1. Some chemical properties of biochar made from different feedstocks

Parameters	Feedstocks			
	Swine dung	Poultry manure	Sawdust	Maize cob
pH in water	7.1	9.59	7.38	8.93

pH in $CaCl_2$	5.82	9.25	6.62	9.04
Available Phosphorous mg kg^{-1}	2.01	1.8	0.42	0.84
Total Nitrogen g kg^{-1}	0.97	0.98	0.07	0.94
Exchangeable bases cmol kg^{-1}				
Na^+	1.14	9.60	1.73	1.09
K^+	19.02	37.7	16.52	28.87
Ca^{2+}	3.58	4.1	15.72	3.41
Mg^{2+}	16.04	12.63	6.81	12.71

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RESPONSE OF COWPEA (*Vigna unguiculata* L. Walp) TO APPLICATION OF STARTER NITROGEN IN MINNA, NIGERIA

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ABSTRACT
The experiment was conducted in the screen house of Federal University of Technology Minna, Nigeria, to determine the response of cowpea to application of starter nitrogen (N). The treatments were 0, 10, 20 and 30 kg N ha^{-1} laid down in a Completely Randomized Design (CRD) with four replications. Data collected were plant height, number of leaves, number of days to flowering, number of days to podding, grain yield and haulms yield. The results showed that the soil was sandy loam, low in organic carbon and phosphorous. At 4, 8, and 10 WAS, application of 30 kg N ha^{-1} had significantly taller plant than control, but statistically similar to 10 and 20 kg N ha^{-1}. The 10 kg N ha^{-1} had the highest grain yield and fresh haulms yield which were significantly higher than control. There was no significant effect of N on the soil chemical properties, except for total nitrogen were application of N resulted in significant increase over that of control. N application increased the growth and yield of cowpea, application of 10 kg N ha^{-1} improved the growth parameters, haulms and grain yield of cowpea assessed.

Keywords: Cowpea, Starter nitrogen, Minna

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is an important grain legume usually grown in the dry savanna of tropical Africa, Asia and South America with over 9.3 million metric tons of annual production (Oritz, 1998). Nigeria is the world's largest producer with about 2.1 million tons followed by Niger with 650,000 tones and Mali with 110,000 tones. FAO (2006) reported that 850 million people in the world with high incidence of undernourishment are in sub-Sahara Africa. Cowpea is mostly intercropped with other crops such as millet, sorghum, pigeon peas, leafy vegetables, bananas, maize and others (Bittenbender *et al., 1984;* Singh *et al.*, 1997). In intercropping system, the spreading indeterminate type of cowpea serves as a ground cover crop which helps in suppressing weeds as well as protects the soil against erosion and in addition, some varieties are suicidal germination of the seed of *Striga hermonthica*, a parasite plant that usually infests cereals with devastating effect (Quin, 1997). Cowpea grain is a rich source of protein, and its haulms, a valuable source of livestock protein (Fatokun, 2002). Both grain and leaves are edible products of cowpea that are rich in protein and cheap sources of protein. On average, cowpea grain contains 23-25 % protein, cooked leaves contain two-third the protein, seven times the calcium, three times the iron, half the phosphorus, eight times the riboflavin, five times the niacin and several hundred times the ascorbic acid and beta-carotene of the cooked seed (Bittenbender, 1990). Cowpea yield are among the lowest in the world, averaging 310 kg/ha (Ofosun-Budu *et al.*, 2007). Consequently, efforts have been made to improve cowpea production in Nigeria through various means including the introduction of new varieties (Addo-Quaye *et al.*, 2011). None of these improved varieties could achieve optimum yield without appropriate fertilizer recommendation. The positive effect on the application of inorganic fertilizer on crop yield and yield improvement has been reported (Carsky and Iwuafor, 1999).

Nitrogen (N) is the most important element needed for crop production. Although, cowpea symbiotically fixes N, plants which are dependent on symbiotically fixed N may suffer from temporary N-fixation during the seedling growth once the cotyledon reserves have been exhausted. It has thus been recognized and demonstrated that application of a small amount of nitrogen fertilizer enhances early vegetative growth (Dart *et al.*, 1977). Nitrogen fertilizer is sometimes also used as a starter doze. Cowpea responds to added fertilizer despite its capacity to fix nitrogen with *Rhizobium* (Sultana, 2003). Although there are divergent views of nitrogen application to legumes, especially cowpea, results of investigation in the tropics have indicated either no response or significant response to nitrogen fertilizer application (Akinola, 1978). It has also been reported that available nitrogenous compound allowed seedlings to make a good start before nitrogen fixation has a chance to occur. Other researchers have shown that plants given inorganic N during vegetative periods were much larger by the onset of flowering than those dependent on symbiotic N fixation (Minchin *et al.*, 1981). Such plants also had more branches and produced many peduncles resulting in greater number of pods, seeds and significantly larger yields.

Despite the importance of cowpea in human diet and animal feed, the yield obtained by most farmers in Nigeria is very low due to the rapid increase in population, there is need to increase production generally and that of cowpea in particular hence the objective of the study is to evaluate the response of cowpea to application of starter N in Minna.

MATERIALS AND METHODS

Study site: The experiment was conducted at the screen house, Federal University of Technology, Gidan Kwano, Minna, Niger State in the Southern Guinea Savanna of Nigeria. Climate of Minna is sub-humid with mean annual rainfall of about 1284 mm. The physical features around Minna consist of gently undulating high plains developed on basement complex rocks made up of granites, migmatites, gneisses and schists. Inselbergs of "Older Granites" and low hills of schists rise conspicuously above the plains. Beneath the plains, bedrock is deeply weathered and constitutes the major soil parent material. The soil has been classified as Typic plinthustalf (Lawal *et al.*, 2012)

Treatments and experimental design: The treatments consisted of four rates of N, (0, 10, 20, 30 kg N ha^{-1}). The experiment was laid out in a completely randomized design (CRD) with four replications to give a total of 16 pots.

Soil sampling and analysis: Surface soil (0-15 cm) collected from the Teaching and Research Farm of the Federal University of Technology, from different points were bulked together to give a composite sample. The soil samples were analysed according to the procedures described by Agbenin (1995). Particle size analysis was carried out by Bouyoucos hydrometer method and textural class, determined using the textural triangle. The soil pH was measured in 1:2.5 soil/$CaCl_2$ suspension with glass electrode pH meter and organic carbon by Walkley-Black method. Available phosphorus (P) was extracted by Bray P1 method. The phosphorus concentration in the extract was determined colorimetrically using the spectrophotometer. Exchangeable acidity was determined by titrimetric titration with standard NaOH. Exchangeable bases, Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} were extracted with 1N NH_4OAc. Ca^{2+} and Mg^{2+} in the extracts were determined using atomic absorption spectrophotometer (AAS) while K^{+} and Na^{+} were determined by flame photometer.

Agronomic practices: Three seed of cowpea variety Sampea 15 (IT99K-573-2-1) was sown in the pot. Two weeks after sowing (WAS), the cowpea plant was thinned to one plant per pot. 10 kg ha^{-1} of phosphorous and potassium was applied at 2 WAS as basal application. Nitrogen fertilizer was applied at 2 WAS. The source of phosphorous and potassium were single super phosphate and muriate of potash respectively while urea was used to supply nitrogen and the fertilizer was applied by ring method. Weeding was also done on a weekly basis by hand pulling.

Growth and yield components: The plant height of cowpea was measured from the base of the plant to the tip of the plant using meter rule at 2, 4, 6, 8 and 10 WAS. Number of leaf was determined by numerical counting of leaves on each plant at 2, 4, 6, 8 and 10 WAS. Number of days to flowering was calculated from the date of sowing to the date when the first flower appeared on each treatment pot and recorded as days to flowering Number of flowers per pot was counted and number of pod per pot was also counted. The pods were harvested, threshed manually, and the grain yield haulms were weighed and also recorded.

Statistical analysis: Data collected were subjected to Analysis of Variance (ANOVA) using the General Linear Model Procedure of Statistical Analysis System (SAS version 9.0) 2002. Treatment means were compared using least significant difference (LSD) at 5 % Level of probability.

RESULTS AND DISCUSSION

The soil physical and chemical properties before sowing are shown in Table 1. The textural class of the soil was sandy loam. The soil was slightly acidic in water (pH 6.5) and the organic carbon (3.12 g kg^{-1}), with available phosphorus (9 mg kg^{-1}) were low and N content was high (0.58 g kg^{-1}) (Esu, 1991). The effect of N on some soil chemical properties is shown in Table 2. There was no significant effect of N on the soil chemical properties after harvest, except for total nitrogen were application of N resulted in significant increase over that of control.

The effect of nitrogen on plant height of cowpea at different growth stages is shown in Table 3. At 2 WAS, all the pots with starter N were significantly taller ($p<0.05$) than the control. At 4, 8, and 10 WAS, the treatment 30 kg N ha^{-1} had significantly taller plant than control, but statistically similar to 10 and 20 kg N ha^{-1}. The effect of starter N on number of leaves are shown in Table 4. The control had significantly higher number of leaves than other treatments at all the growth stages of the plant except at 2 WAS. There was however no significant difference amongst the other treatments at all the growth stages of the plant. The effect of N on yield components of cowpea are shown in Table 5. Application of starter N had no effect on flowering and podding of the plant. All the plants flowered and podded at the same time. Similarly, all the plants produced statistically similar number of pods. Effect of N on grain yield of cowpea was shown in Figure 1. The treatment 10 kg N ha^{-1} recorded the

highest grain yield and the lowest was observed in 0 kg N ha^{-1}.

The pH of the soil which was slightly acidic and favourable for accessibility of plant nutrients as most plant nutrients are available for plant uptake at pH 5.5- 6.5 (Brady and Weil, 2002). The N content of the soil is high probably due to prior cultivation of land with fertilizer or incorporation of crop residue. Giller (2001) reported that N increases the growth of plant. The reduction of flowering and podding duration was observed, this might be due to enhanced supply of carbohydrate to active reproductive parts (Giller *et. al.*, 1991). Afolabi *et. al.*,(2013) observed an increase in plant height, shoot biomass, leaf number as result of application of nitrogenous fertilizer with phosphate fertilizer to cowpea. Sultana (2003) also reported that plant height increased due to increase in N fertilizer to cowpea.

Nitrogen application increases yield of cowpea. This increase might be due to the positive effect of N element on plant growth which leads to progressive increase in internodes length and consequently plant height. Several reports had earlier attributed significant increase in the development of vegetative plant parts and dry matter accumulation with N application, as N is an important constituent of chloropyll, amino acid and nucleic acid (Anjorin, 2013). The improvement in plant growth also corroborated the findings of Cox *et. al.,* (1993); Sumi and Ketayama, (2000) also reported that N promotes higher leaf area development and reduced rate of senescence. The application of N increased the grain yield of cowpea. This is in agreement with the findings of Minchin *et al*. (1981) who showed that cowpea plants supplied with nitrogen fertilizer had more branches, produced many peduncels and so greater number of pods, seeds, and significantly larger grain yields than those dependant on symbiotic nitrogen fixation.

CONCLUSION AND RECOMMENDATIONS

From the result of this study, N application increased the plant height, haulms and grain yield of cowpea. Application of 10 kg N ha^{-1} improved the growth parameters, haulms and grain yield of cowpea, suggesting that application of 10 kg N ha^{-1} will improve the performance of cowpea Sampea 15 (IT99K-573-2-1) assessed. A field trial should be conducted to ascertain this finding.

Table 1: Physical and chemical properties of the soil used for the experiment

Parameters	Values
Sand (g kg^{-1})	858
Silt (g kg^{-1})	40
Clay (g kg^{-1})	102
Textural class	Sandy loam
pH in water at 1:2.5	6.5
Organic Carbon (g kg^{-1})	3.12
Total Nitrogen (g kg^{-1})	0.58
Available phosphorus (mg kg^{-1})	9
Exchangeable Bases (cmol kg^{-1})	
Ca^{2+}	4.12
Mg^{2+}	1
K^{+}	0.09
Na^{+}	0.16
Exchangeable acidity (cmol kg^{-1})	0.02
ECEC	5.39

Table 2: Effect of nitrogen fertilization on some soil chemical properties after harvest

Treatment (kg N ha-1)	EK (cmol kg-1)	AP (mg kg-1)	OC (g kg-1)	TN (g kg-1)
0	0.06	5.23	9.73	0.5
10	0.06	5.53	10.4	0.66
20	0.07	5.14	6.4	0.8
30	0.06	4.74	8	0.55
LSD	0.009	0.45	2.13	0.14

EK: Exchangeable potassium AP: Available phosphorus OC: Organic Carbon TN: Total Nitrogen

Table 3: Effect of nitrogen on cowpea plant height

Treatment (kg N ha-1)	Plant height (cm)				
	2 WAS	4 WAS	6 WAS	8 WAS	10 WAS
0	18.2	24.2	31	33.6	33.6
10	27.3	29.1	38	40.2	40.3
20	25.4	30.6	37.3	40.2	40.2
30	26.2	31.1	45.1	41.8	41.8
LSD	3.81	3.15	6.67	4.49	4.83

WAS: weeks after sowing

Table 4: Effect of nitrogen on cowpea number of leaves

Treatment (kg N ha^{-1})	Number of leaves				
	2 WAS	4WAS	6WAS	8WAS	10WAS
0	7	20	26	36	37
10	11	15	21	22	24
20	8	13	17	20	22
30	9	14	19	23	23
LSD	2.19	4.43	3.93	7.30	7.13

WAS: weeks after sowing

Table 5: Effect of nitrogen on cowpea yield components

Treatment (kg N ha^{-1})	DTF	DTP	NPPP	FHY	DHY
0	46	58	2	8.59	3.36
10	47	59	3	16.77	5.08
20	44	62	3	10.78	3.46
30	51	56	3	14.95	4.03
LSD	3.57	2.56	0.54	3.89	0.85

DTF: Days to flowering, DTP: Days to podding, NPPP: Number of pods per plant
FHY: Fresh haulms yield DHY: Dry haulms yield

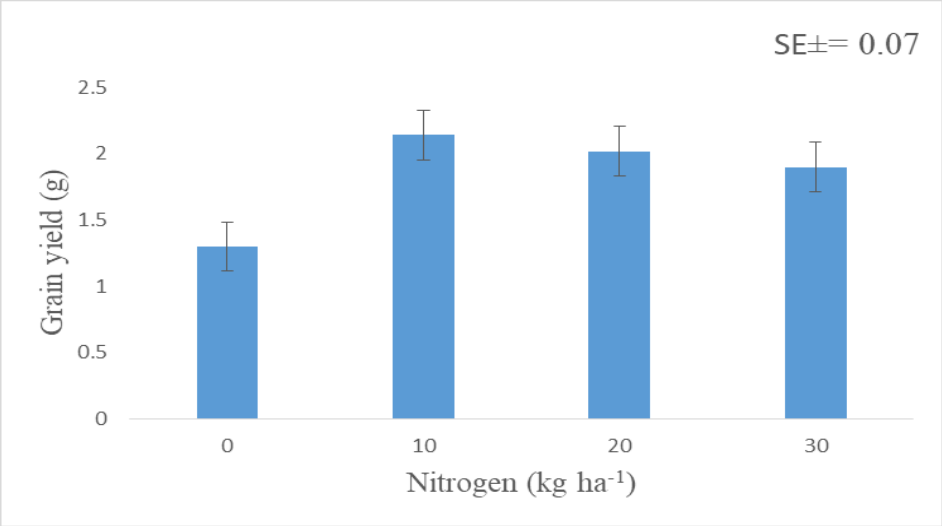

Figure1: Effect of nitrogen on cowpea grain yield

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PRICE BEHAVIOUR OF LOCAL AND IMPORTED RICE IN RURAL AND URBAN MARKETS OF NIGER STATE, NIGERIA

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ABSTRACT
The study analysed the price behaviour of local and imported rice in rural and urban markets of Niger state, Nigeria, specifically the study examined the trend in prices, determined the co-integration between the price series and ascertained the movement and direction of prices. Secondary data which were the average monthly retailed prices of local and imported rice in rural and urban markets per kilogram of rice was used from January 2000 to December 2016 (204 observations). The data were sourced from Niger Sate Bureau of Statistics and were analysedusing descriptive statistics, Augmented Dickey Fuller (ADF) test, Johansen Cointegration Model, Error Correction Model (ECM) and Granger Causality test. The result shows that the mean prices of local rice in rural and urban markets were ₦41.13 and ₦116.22 per kilogram respectively, while that of imported rice was ₦201.85 and ₦207.55 respectively and the kurtosis shows that the variables were normally distributed, while the trend shows an upward and irregular pattern in the prices of both local and imported rice in the two markets. The ADF test shows that the variables were stationary at first difference I(1), while Johansen test indicated the presence of cointegration among the local and imported rice prices in the markets as shown by the trace statistics and max Eigen statistics which were significant at 5% level of probability each. The ECM result shows that there is a long run relationship among the prices but there was a low speed of adjustment in the short run as indicated by the coefficient of -0.0139. The Granger causality result shows a unidirectional causal relationship between prices of imported rice in rural and urban markets and also in prices of local rice in urban and rural markets over the period of study. It is recommended that the flow of market information should be enhanced by the marketers and also government should be firm on its policy on rice.

KEY WORDS: Price trend, local and imported rice, urban and rural markets.

INTRODUCTION

Global demand for agricultural products is expanding rapidly and the demand for food products is foreseen to continue to grow for several decades as a result of a combination of population growth, rising per capita incomes and urbanisation (Nasirin *et al.*, 2015). Cereal grains have been the principal component of human diet, more than 50% of world daily caloric intake is derived directly from cereal grain consumption (Joseph, 2011). Rice is the most important staple food for about half of the human race (Imolehin and Wada, 2000).

The demand for rice in Nigeria has been soaring over the years (Ayanwale *et al*, 2011).Since the mid1970s, rice consumption in Nigeria has risen tremendously growing by 10.3% per annum. According to Federal Ministry of Agriculture and Rural Development (FMARD), (2011), there is an increasing demand for rice in Nigeria, as rice consumption was 5 million metric tons in 2010 and is expected to reach 36 million metric tons by 2050. According to NBS (2012), a study on household expenditure by commodity, shows that urban households spend 8.65% of their income on rice while the rural householdsuse up to 9.07% of their income on rice. A combination of various factors seems to have triggered the structural increase in rice consumption over the years with consumption broadening across all socio-economic classes, including the poor (Oyinbo *et al.*, 2013). According to the(Global Agriculture Information Network GAIN, 2012), the rising demand is as a result of increasing population growth and income level.In 2016 the estimated demand for rice stood at 6.3 million tons, while the supply was 2.3 million tons (FMARD, 2016). And according to Daramola (2005) and Awe (2006) any shortfall in supply of rice creates incentive for rice importation in the country, which reduces the country's foreign exchange earnings.

Prices are signals that direct and coordinate not only the production and consumption decisions but also the marketing decisions over time, form and space (Kohls and Uhl, 2001),Price is a major endogenous determinant of supply and demand,the price of the commodity is center to its transaction, and the quantity bought by buyers usually depend on their purchasing power in relation to the price. According to Mondal (2010), agricultural produce prices are notoriously unstable and consequently, price instability leads to uncertainty in the income of the producers as well as the quantity purchased by the consumers.

Niger State is a rice producing state with an average production rate of 5 tons per hectare and this rank the state as the highest producer of rice in Nigeria

(Jalingo,2017), also Niger State Ministry of Agriculture (2017), estimated rice production figure shows a yield of 5.31 tons per hectare. Also according to the National Agricultural Extension and Research Liason Service (NAERLS,2019), Niger State has the highest increase in rice production in 2017 and 2018 cropping season. Despite the availability of rice in the state, the price of rice has been on the increase. According to Paulin (2011), the continuous and persistentincrease in price of food commodities can lead to food insecurity and significantly affects the poor people in both urban and rural areas, as their purchasing power erodes as prices increase. According to Burakov,(2016) a rise in food prices put pressure on the household sector of an economy.

Therefore, fluctuations in the prices of agricultural products (especially major staples) have become of great concern to economists and policy makers (Adekoya *et al.*, 2013). Thus, there is need to know the trend in the prices, the direction of the movement in prices between rural and urban markets among other things to be able to inform and guide policy makers adequately.

Objectives of the Study: The aim of the study is to examine price behavior of local and imported rice in rural and urban markets of Niger state.

Theobjectives are to;

i. examine the trend in prices of local and imported rice in rural and urban markets in the study area,
ii. determine cointegration between prices of local and imported rice in rural and urban markets in the study area, and
iii. ascertain the lead market between rural and urban markets for local and imported rice in the study area.

METHODOLOGY

Study Area: The study area is Niger State (North Central) Nigeria. Niger State was carved out of the former North-Western State in 1976.The State lies between Latitudes 8º20' and 11^0 30' North and Longitudes 3º30' and7^0 20' East and share border with the Republic of Benin (West), Zamfara State (North), Kebbi (North-West), Kogi (South), Kwara (South-West), Kaduna (North-East) and South-East by FCT Abuja (National Bureau of Statistics (NBS), 2009). The 2006 population census shows that Niger state has a population of 3,950,249 with an annual growth rate of 3.4% (National Planning Commission (NPC), 2006). The projected population at 3.4% annual growth rate gives a population of 5,293,333 by 2016,Niger State is the largest States in Nigeria by land mass, covering about 86,000km^2 (or about 8.6 million hectares) representing about 9.3% of the total land area of the country (Development Action Plan for Niger State, 2008).Estimated 95% of the land is arable and serves as source of employment for the predominantly rural population whose primary occupation is farming.

Niger State experiences two distinct climatic seasons in a year.These are rainy and dry seasons. Rainfall is steady and evenly distributed, usually between May and November. Its maximum temperature is normally 37^0C which is recorded between March and June, while minimum temperature is around 21^0C recorded between December and January (Development Action Plan for Niger State, 2008).

Method of Data Collection and Sample Size: This study used secondary data which are average monthly retailed prices of local and imported rice for rural and urban markets in Niger State. The data were collected fromNiger State Bureau of Statistics and Niger State Ministry of Agriculture, for a period of 17years that is from January, 2000 to December, 2016, thus the number of months under study is 204 months.

Method of Data Analysis: The study applied descriptive statistics, Augmented Dickey Fuller (ADF) test for stationarity, Vector Autoregressive Model (VAR), Co-integration and Granger Causality test. The presence of unit root in a time series means the series is nonstationary and this generates unreliable results regarding the hypothesis testing According to Upender (2012), one method of testing for unit root and the order of integration of time series is the use of ADF.

Given the autoregressive process of order one AR (1),

$$Y_t = \phi\, Y_{t-1} + e_t \qquad (1)$$

When constant and trend is added to equation 1, it becomes

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \beta Y_{t-1} + \phi_i \sum_{i=1}^{m} \Delta Y_{t-1} + e_t \qquad (2)$$

Where; Y_t = price in time t,

Δ = first difference operator

α ,$\beta$and ϕ_i = parameters to be estimated

e_t = a serially uncorrelated white noise error term .

if $\phi = 1$, the serie Y_t is nonstationary, if $\phi < 1$ then the series Y_t is stationary.

Also, a suitable lag was selected for each of the analysis using the various lag length selection criteria such as Akaike's information criterion, Schwarz information criterion, Hannan-Quinn criterion, Final prediction error and Corrected version of AIC:

Descriptive statisticswere used to achieve objective 1, where summary statistics of the pricesincluding mean, minimum, maximum, skewness, kurtosis as well as graphs were used to examine the trend in the price series.

Johansen co-integration test was used to achieve objective 2.The variables were modelled as Vector Autoregressive Model (VAR). The general model is specified as;

$\Delta p_t = \propto + \sum_{i=1}^{k-1} \Gamma_i \, \Delta p_{t-1} + \sqcap \, p_{t-1} + \mu_t$ (3)

Where;

Δ = is the first difference operator,

p_t =is a n x 1 vector containing the price,

Γi = The matrix of short run coefficients,

Π = The matrix of long–run coefficients,

μ_t = The normally distributed errors and

K = Number of lags that will be adequately large enough to capture the Short-run dynamics of the underlying VAR and to produce normally distributed white noise residuals.

Granger causality test was used for objective 3,The Granger model for this study as adopted from Izekor *et al*., (2016)is represented as;

$$RP_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \, UP_{t-1} + \sum_{j=1}^{n} \beta_j \, RP_{t-j} + \varepsilon_t \quad (4)$$

Where;

n = number of observations,

M = number of lag ,

RP_t = rural market price,

UP_t = urban market price,

α and β = parameters to be estimated and

ε_t = error term

Hypothesis

H_0: price of rice in rural market does not determine the price of rice in urban market for local and imported rice.

H_1: price of rice in rural market determine the price of rice in urban market for local and imported rice.

RESULTS AND DISCUSSIONS

The summary statistics of the prices showed that the minimum and maximum prices for local rice was ₦28.97 and ₦325.98, ₦20.01 ad ₦276.68 in urban and rural markets respectively and ₦150.04 and ₦345.87, ₦135.59 and ₦346.02 in urban and rural markets respectively for imported rice in Niger State. Furthermore, all the prices were positively skewed to the right, implying that the data all have positive values. Price of imported rice for both rural and urban markets in Niger State were significant at 1% probability level ($P < 0.01$) while price of local rice in both rural and urban markets of the study area were significant at 5% probability level ($P < 0.05$) indicating that these variables had the kurtosis matching that of a normal distribution.

The trend in the rice price series were visualized by the use of graphical plots, the trend in urban and rural market prices of local rice in Niger state as shown in figure 1. has been increasing and the urban market price was always higher than the rural (producing) market, but at the tail end in 2016 prices were almost very close with a little difference between the rural and urban markets especially in the months of 196-200 that is April-August 2016.

Figure 2 shows the trend in imported rice prices in both rural and urban markets. The price series for both markets shows almost the same pattern throughout the period under study. This may be attributed to the fact that the rice was imported into the state.

The ADF test for stationarity as presented in table 1, shows that although all the variables were non stationary at levels but became stationary at first difference with order of integration 1, I(1). This result is in accordance with the result of Emokaro and Ayantoyinbo (2014) who observed the same with monthly price series of local rice in Osun State. Also, all the variables were all significant at 1% probability level ($P < 0.01$).

Since all the variables were integrated of the same order 1(1), Johansen test for cointegration was used to determine long run relationship for the variables. The result as presented in table 2 shows a tracestatistic of 351.6595 which is greater than the critical value 47.21 at 5% level of significance ($P < 0.05$); this indicates that there was one co-integration equation among the variables. Therefore, based on the decision rule, the null hypothesis of no co-integration among the variables price of imported rice in rural and urban areas and price of local rice in rural and urban areas of Niger State was rejected. This implies that there is a long run relationship among the variables. The result was also confirmed by the Max Eigen statistics of 133.2789 which is greater than the critical value of 47.21 at 5% level of significance ($P < 0.05$) thereby indicating the presence of co-integration among the variables. This result is in line with those of Ojo *et al*., (2015) and Akpan (2014), which all revealed the presence of co-integration between price series.

Since the variables were co-integrated, an Error Correction Model (ECM) was carried out to ascertain the speed of adjustment of the price series. Table 3 shows that in the long run, the result of ECM shows that the ECM coefficient (-1.1089) was negative and statistically significant at 1% probability level ($P < 0.01$) this is an indication that there is a long run relationship between the prices during the period under study. The result also shows that the coefficient of price of imported rice in the rural areas and price of local rice in urban areas of Niger State were positive and statistically significant at 1% ($P < 0.01$) probability level.

In the short run, the ECM coefficient as presented in table 3 was -0.0139, which indicates a low speed of adjustment of the variables towards equilibrium. This implies that the speed of adjustment at which

the variables used in the model will be in equilibrium is at the rate of 1.39%. The values of the information criteria 30.8229, 31.1097 and 31.5319 for Akaike information, Hannan Quin and Schwarz respectively shows that the error in the model had been corrected.

The result of the Granger causality test among the prices as presented in table 4 shows that there is a unidirectional causal relationship between price of imported rice in the rural markets of Niger State and price of imported rice in the urban markets of Niger State. That is, the price of imported rice in the rural markets of Niger State granger causes the price of imported rice in urban markets of Niger State. This implies that the price of imported rice in the rural markets of Niger State can be used to predict the price of imported rice in the urban markets of the State. Hence, the null hypothesis of no granger causality was rejected at 1% probability level ($P < 0.01$).

The result also shows a unidirectional causal relationship between price of local rice in the urban markets of Niger State and price of local rice in the rural markets of Niger State. That is, the price of local rice in the urban areas of Niger State granger causes the price of local rice in the rural areas of Niger State. This implies that the price of local rice in the urban areas of Niger State can be used to predict the price of local rice in the rural areas of the State. Hence, the null hypothesis of no granger causality was rejected at 10% probability level ($P < 0.10$).

Table 1: Augmented Dickey Fuller (ADF) Unit Root Test for the Price series

Variable	Level	1st Difference	Order of Integration	Critical Value (1%)	Critical Value (5 %)
PNUI	-0.035 (0.9555)	-13.819*** (0.0000)	I(1)	-3.476	-2.888
PNRI	-1.140 (0.6987)	-15.169*** (0.0000)	I(1)	-3.476	-2.888
PNUL	1.440 (0.9973)	-12.078*** (0.0000)	I(1)	-3.476	-2.888
PNRL	-0.560 (0.8797)	-13.827*** (0.0000)	I(1)	-3.476	-2.888

Source: Output from data analysis, 2018.
***implies significant at 1% probability level
Figures in parenthesis are probability values.
PNUI = Price of Niger Urban Imported Rice; **PNRI** = Price of Niger Rural Imported Rice; **PNUL** = Price of Niger Urban Local Rice; **PNRL** = Price of Niger Rural Local Rice

Table 2: Johansen Co-integration Test for the monthly price series

Hypothesized No. of CE(s)	Max Statistics	Trace Statistics	Critical Value (5%)
None*	133.2789	351.6595	47.21
At most 1	90.6943	218.3806	29.68
At most 2	87.1296	127.6863	15.41
At most 3	40.5568	40.5568	3.76

Source: Output from data analysis, 2018.
***** implies rejection of null hypothesis at 5% probability level.

Table 3: Estimates of the Vector Error Correction Model for the price series

Variable	Coefficient	Standard Error	t-statistics
Long Run			
ECM (-1)	-1.1089	0.1923	5.77***
PNRI (-1)	-0.5095	0.0549	9.28***
PNUL (-1)	-0.2922	0.0753	3.88***
PNRL (-1)	-0.0425	0.0451	0.94
Constant	0.0834		
Short Run			
ECM (-1)	-0.0139	0.0293	1.12
PNUI (-1)	0.1151	0.1521	0.76
PNUI (-2)	0.0635	0.0958	0.63

PNRI (-1)	-0.3672	0.0816	4.50***
PNRI (-2)	-0.1632	0.0550	2.97***
PNUL (-1)	-0.1707	0.0977	1.75*
PNUL (-2)	0.0081	0.0908	0.09
PNRL (-1)	0.0129	0.0401	0.32
PNRL (-2)	0.0434	0.0398	1.09
Constant	-0.0137	0.7043	0.02
Log likelihood	-3039.277		
AIC	30.8228		
HBIC	31.1097		
SC	31.5319		

Source: Output from data analysis, 2018.
*****, **** and ***** implies significant at 1%, 5% and 10% probability level respectively.
PNUI = Price of Niger Urban Imported; **PNRI** = Price of Niger Rural Imported; **PNUL** = Price of Niger Urban Local; **PNRL** = Price of Niger Rural Local; **AIC** = Akaike information criterion; HBIC = Hannan Quinn Criterion; **SC** = Schwarz criterion.

Table 4: Result of granger causality test

Null Hypothesis	F-ratio	Prob > F	Decision
PNUI does not granger cause PNRI	0.18727	0.8294	Accept
PNUI does not granger cause PNUL	2.3111	0.1020	Accept
PNUI does not granger cause PNRL	0.70307	0.4964	Accept
PNRI does not granger cause PNUI	10.069	0.0001	Reject
PNRI does not granger cause PNUL	2.0137	0.1364	Accept
PNRI does not granger cause PNRL	0.0045	0.9955	Accept
PNUL does not granger cause PNUI	0.29773	0.7429	Accept
PNUL does not granger cause PNRI	2.013	0.1365	Accept
PNUL does not granger cause PNRL	2.4168	0.0920	Reject
PNRL does not granger cause PNUI	0.6477	0.5260	Accept
PNRL does not granger cause PNRI	0.0377	0.9630	Accept
PNRL does not granger cause PNUL	1.586	0.2075	Accept

Source: Output from data analysis, 2018.
PNUI = Price of Niger Urban Imported; **PNRI** = Price of Niger Rural Imported; **PNUL** = Price of Niger Urban Local; **PNRL** = Price of Niger Rural Local.

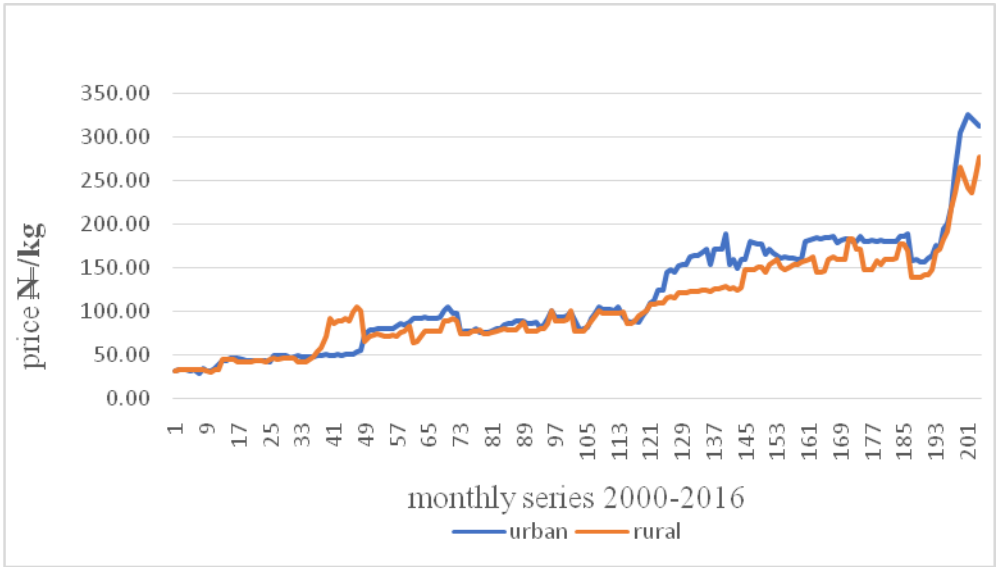

Figure 1: Trend in urban and rural market prices of local rice in Niger State

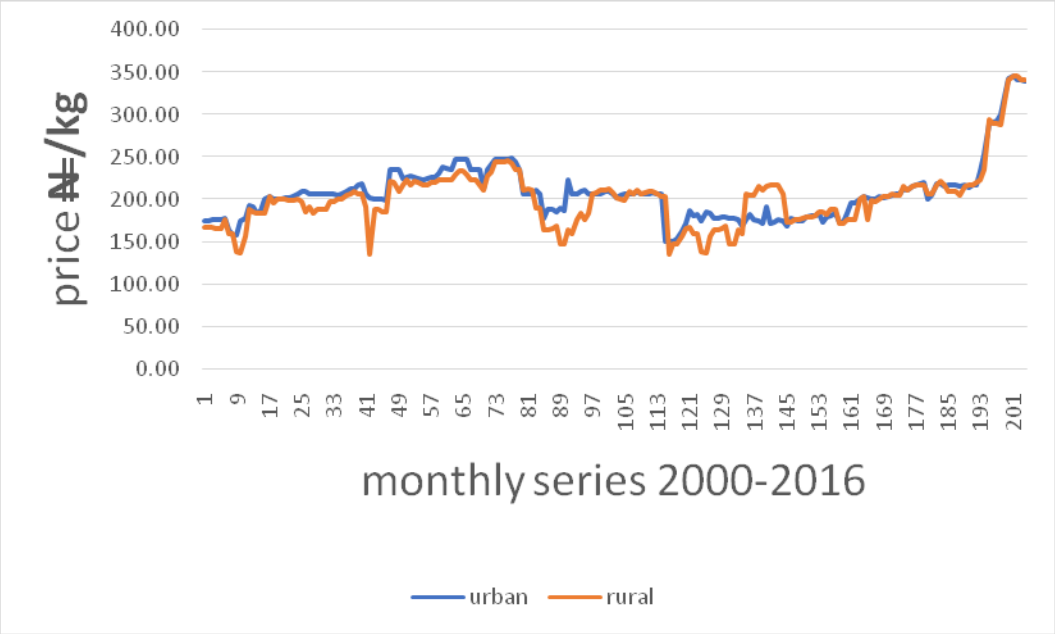

Figure 2: Trend in urban and rural market prices of imported rice in Niger State

CONCLUSION AND RECOMMENDATIONS

The result of the study has shown that prices of local and imported rice was increasing over the period under study, and were integrated of order one I(1). The prices are connected in the long run but have a low speed of adjustment in the short run. Though the null hypothesis of the granger causality of most of the market pairs were accepted, the alternative hypothesis was accepted for pairs of rural imported and urban imported as well as price of urban local and rural local which are all unidirectional.

It is recommended that the flow of market information should be enhanced by marketers, government policy on ban on the importation of rice should be firm and also local production should be enhanced and fully supported by government to close demand supply gap.

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