Nourrir le Monde sans l'empoisonner

FEEDING THE WORLD WITHOUT POISONING

Scientific Track Proceedings of the 6th West African Organic Conference/
6ème Conference Ouest Africaine De L'agriculture Biologique
November 23-26, 2021, Royal Beach Hotel,
Ouagadougou, Burkina Faso

Editors
AdeOluwa, O.O.
Ologundudu, O.M.
Oloore, N.O.

6TH WEST AFRICAN ORGANIC CONFERENCE
Burkina Faso 2021
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شبكة الباحثين في الزراعة العضوية بإفريقيا

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Objectives of the Conference

The potential of organic agriculture in the transformation of national and regional economies, ecologies and livelihoods through income growth, climate change adaptation, food sovereignty and trade is explored and showcased.

The sharing of knowledge, information, experiences and skills among all stakeholders in the organic sector is facilitated, especially between West-African farmers and their national and sub-regional representations is facilitated.

Scientific evidence is presented on the capability of organic agriculture in contributing to the transformation of national and continental economies, enhancement of systems resilience and mitigation of climate change, among others.

The uptake of organic alternatives through south-south collaboration, especially, in the sharing of experiences is encouraged.
Organic produce and products are exhibited to stimulate national, regional and international trade and link producers to markets.
The conference is showcased and publicised to create awareness, obtain support and buy in among policy makers, organic stakeholders and the general public.

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About US

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The Network of Organic Agriculture Researchers in Africa (NOARA) was established to unite and coordinate African organic and ecological agriculture scientific and technical researchers within and outside Africa. The network is an African initiative.

NOARA is a network independently established by African organic researchers that met at Modena, Italy, in 2005 but was later launched in 2009, during the 1st African Organic Conference in Kampala. During the 2nd African Organic Conference (2nd AOC) held in Lusaka, Zambia, in May 2012, a side event brought together participants from almost all regions of Africa and Europe to discuss how to develop organic agriculture research agenda. Research was underscored as a critical component of any initiative designed to promote ecologically sustainable development of agriculture in Africa.

The 4th AOC in 2018 General Assembly at Saly, Senegal, recommended AfrONet to revive NOARA and probably re-organize the Network for effectiveness in its expected roles. A Coordinator was therefore appointed in March 2019 to build NOARA and ensure proper functionality of the Network.

NOARA VISION

Africa with zero hunger, poverty eradicated, improved livelihoods and sustained ecosystem through innovative organic and ecological agriculture research.

NOARA MISSION

To generate and disseminate sound evidence-based scientific organic agricultural knowledge that can ensure healthy, ecological, fairness and care of organic agriculture actors in Africa for sustainable livelihood and ecosystem, leading to food security, income and sustainable development.

NOARA SPECIFIC OBJECTIVES AND RESEARCH PRIORITIES

Thematic area 1: Research and Training

i. Lead research agendas on organic and ecological agriculture in Africa.
ii. Coordinate organic and ecological agriculture training and research in Africa.
iii. Support or initiate research activities that will contribute to the social, cultural and economic productivity of Africa's smallholder farmers, processors and marketers, particularly, women and youths who have been largely marginalized.
iv. Demonstrate success stories useful for up scaling organic and ecological agricultural practices.

Thematic area 2: Policy and Stakeholders' Engagements

i. Promote collaboration among organic and ecological agriculture researchers, practitioners, farmers and policy makers in Africa.
ii. Foster improved ecological organic agriculture database, to influence policy development in Africa.
iii. Advocate for the mainstreaming of organic and ecological agriculture into agricultural research and innovation to enhance food security in Africa.
iv. Engage organisations producing organic and ecological inputs in confirmatory and adaptive research for possible recommendation of their products to end users in Africa and beyond.

Thematic area 3: Conferences and Information Dissemination

i. Organize conferences and meetings for the exchange of information on organic and ecological agriculture.
ii. Publish research and technical results on organic and ecological agriculture.
iii. Organise consortia of experts to address specific or emerging issues relating to organic and ecological agriculture in Africa.

Thematic area 4: Networking, Advocacy and Awards

i. Enhance partnerships for organic and ecological agriculture research in Africa and beyond.
ii. Map out like-minded organisations.
iii. Honour distinguished members as fellows of the network.
iv. Represent the interest of organic and ecological agriculture researchers within and beyond Africa.

NOARA KEY SERVICES

Some of NOARA key functions to meeting the stated objectives includes to: (within and outside Africa)

a. Undertake lobbying and advocacy on organic and ecological agriculture research at high levels.
b. Support capacity building for key players in organic and ecological agriculture across the continent.
c. Mobilize resources for NOARA's endeavours in promoting organic agriculture on the continent.
d. Spearhead organic agriculture research, extension, training and value chains and market development.
e. Provide management and administrative consultancy to like-minded programmes and partners on organic agriculture research; and,
f. Undertake any other functions as deemed necessary to address NOARA's objectives.

Membership

NOARA is a membership Network that draws members from national, regional, continental and international organic agriculture organisations, associations, networks and companies within and outside Africa, but whose aims and goals are in support of organic and ecological agriculture.

AFRICAN JOURNAL OF ORGANIC AGRICULTURE AND ECOLOGY (ISSN: 2734-2913)

AFRICAN JOURNAL OF ORGANIC AGRICULTURE AND ECOLOGY

African Journal of Organic Agriculture and Ecology (AJOAE) is a journal of Organic Agriculture and Ecology published biannually to create an effective medium for dissemination of information on organic agriculture research findings in all areas of Agriculture, Food sciences and Ecology. The Journal International Standard Serial Number (ISSN) is 2734-2913.

Scope

Contributions may be on Agricultural Economics, Agricultural Engineering, Agricultural Extension, Agroforestry, Animal science, Crop/Environmental protection, Crop science, Environmental Sciences, Fishery/Aquaculture, Pharmacy, Soil science, Veterinary Medicine, Wildlife Management.

Careful editing and scrutiny are required before sending manuscript to the editor as no room for alteration may exist once an article is accepted for publication based on reviewers' comments.

Contributors are to send their manuscripts, not previously published or being considered for publication elsewhere to:

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Operational Capacity Gaps of Organic and Ecological Agriculture Stakeholders in West Africa

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Abstract

Food insecurity is one of the most significant problems in the world today. This is because it affects one third of the global population, threatening human survival. Food insecurity which is mostly caused by increasing populace places a substantial burden on the society through social cost, social unrest, famine, rising prices and healthcare. Sustainable food production which organic agriculture addresses is one of the ways of alleviating food insecurity. Organic and ecological agriculture are fast growing agricultural system that supports food sustainability. While organic food production is increasing in most developed countries, it is not so in most West African countries. It has been observed that high capacity of organic and ecological agriculture stakeholders in developed countries could have contributed to the high production of organic foods, hence, the need to assess the operational capacity of stakeholders in West Africa. A survey was carried out to gather information on capacity operational gaps among stakeholders of organic and ecological agriculture in West Africa. The survey utilized e-questionnaire to collect data from 214 organic practitioners across West African countries. Participants from nine countries were captured. The countries are Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Mali, Nigeria and Togo. Twelve categories of operations the stakeholders were identified. They include: Education/training, Technical Partners, Researchers, Media Practitioners, Extension Service Providers, Farmers, Consumers, Civil Society Organization, Processors, Input Producers, Policymakers, and Marketers. The operational capacity gaps identified are in the following order : Unavailability of organic inputs (76) > Lack of information (61) on organic agriculture > Insufficient funds for organic agriculture (59) > Inaccessibility to organic market (50) > Improper pest and disease management (43) > inadequate training (42) and Advocacy of organic agriculture (42) > Poor Government policy (41) and Lack of modern equipment (41) as well as Poor government policy on organic agriculture (41) > Unaffordability of organic input (27) > High cost of certification (25) > Poor research on organic agriculture (23) > inadequate organic agriculture technical personnel/extension agent (17) > improper networking among organic organization body in West Africa (14) > Inadequate processing, storage and value addition chain (12) and Improper soil management for organic farming (12). Development of Organic and Ecological Agriculture in West Africa could be enhanced if adequate attention is paid to the revealed capacity gaps of the stakeholders.

Les Defis en Matière de Capacités Opérationnelles Des Acteurs de L'agriculture Biologique et Écologique en Afrique de L'ouest

Résumé

De nos jours, l'insécurité alimentaire est l'une des grandes préoccupations dans le monde. En effet, elle touche un tiers de la population mondiale ainsi menaçant la survie humaine. L'insécurité alimentaire, qui est principalement causée par l'augmentation de

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la population, impose un fardeau considérable à la société en raison des coûts sociaux, des troubles sociaux, de la famine, de la hausse des prix et des soins de santé. La production alimentaire durable à laquelle s'adresse l'agriculture biologique est l'un des moyens de réduire l'insécurité alimentaire. L'agriculture biologique et écologique est un système agricole à croissance rapide qui soutient la durabilité alimentaire. Alors que la production d'aliments biologiques augmente dans la plupart des pays développés, ce n'est pas le cas dans la plupart des pays d'Afrique de l'Ouest. Une enquête a été menée pour recueillir des informations sur les défis opérationnels des capacités parmi les acteurs de l'agriculture biologique et écologique en Afrique de l'Ouest. L'enquête a utilisé un questionnaire électronique pour collecter des données auprès de 214 acteurs de l'agriculture biologique dans les pays d'Afrique de l'Ouest. Les participants à cette enquête proviennent de neuf pays ; Bénin, Burkina Faso, Côte d'Ivoire, Gambie, Ghana, Guinée, Mali, Nigéria et Togo. Douze répartitions d'opérations des acteurs ont été identifiées. Elles sont : l'éducation/la formation, les partenaires techniques, les chercheurs, les professionnels des médias, les prestataires de services de vulgarisation, les agriculteurs, les consommateurs, les organisations de la société civile, les transformateurs, les producteurs d'intrants, les décideurs, les spécialistes du marketing. Les déficits de capacités opérationnelles identifiés sont dans l'ordre suivant : Indisponibilité des intrants biologiques (76), manque d'informations (61) sur l'agriculture biologique, insuffisance de financement pour l'agriculture biologique (59), Inaccessibilité de marché biologique (50),gestion inapproprié des maladies et ravageurs (43), formation inadéquate (42) et Plaidoyer pour l'agriculture biologique (42) , Mauvaise politique gouvernementale (41) et Manque d'équipements modernes (41) ainsi que Mauvaise politique gouvernementale sur l'agriculture biologique (41) , Inaccessibilité des intrants biologiques (27) , Coût élevé de la certification (25) , Mauvaise recherche sur l'agriculture biologique (23) , Personnel technique/agent de vulgarisation de l'agriculture biologique inadéquat (17) , Mauvaise mise en réseau des organisations biologiques en Afrique de l'Ouest (14) , Transformation inadéquate, chaîne de stockage et de valeur ajoutée (12) et Mauvaise gestion des sols pour l'agriculture biologique (12). Le développement de l'agriculture biologique et écologique en Afrique de l'Ouest pourrait être amélioré si une attention adéquate est accordée aux défis de capacité révélées des acteurs.

Introduction

Food insecurity is one of the most significant problems in the world today. It affects one third of the global population and it is a concern for human survival. It is an extremely high priority in the developing region of the world were population growth and increase in environmental event such as erosion and flood pose a threat on food security (Ahmed *et al.,* 2017). The main causes of food insecurity are poverty, war and conflict, natural disasters, climate change etc. (Prosekov *et al*., 2018). All the causative factors place a substantial burden on the society through social cost, social unrest, famine and rising prices of food.

Sustainable food production, which organic and ecological agriculture address, is one of the ways of alleviating food insecurity. Organic and ecological agriculture are fast growing agricultural systems that support food sustainability. While organic food production is increasing in most developed countries it is not so in most West African countries.

The current available estimates indicate that about 795 million people in the world – just over one in nine – were undernourished in 2014 to16, whereas the projection in Africa alone was 233 million people (FAO, IFAD and WFP, 2015). In West Africa, approximately 34 million people were projected to be undernourished between 2014 - 2016 (FAO, 2015). Although, the region is making positive strides to recue hunger within the shortest possible time, the situation is alarming in many member countries. Studies have shown that countries with large food insecure populations are often also those whose agricultural systems are highly susceptible to climate influences, particularly in Sub-Saharan Africa (FAO, 2014;

Gregory *et al*., 2005). It is imperative to create new system that will help meet food insecurity in West Africa. Organic and ecological agriculture as components of agriculture are fast developing globally as sustainable food system approaches.

Organic and ecological agriculture support food sustainability, as well as contribute to achievement of the Sustainable Development Goals (SDGs) (Setboonsarng *et al*., 2017). There has been an increasing demand for organic food products due to increasing consumers' awareness of healthy food consumption in recent decades (de Schaetzen, 2019). Global organic sector was valued at 106b Eur in 2019, with total organic area of 72.3 million hectares, managed by over 3.1 million producers (FibL, 2021). The organic market is expanding because there is high demand driven by perceptions and beliefs among consumers, also there is increased general public support for organic producers and their products (Nguyen *et al.,* 2019, Soroka *et al.,* 2019).

Enhancing agricultural development in Western Africa to meet up with world production standards entails partnership among member countries (FAO and African Development Bank Group, 2015). The welfare of organic and ecological agriculture thriving well through partnership among its stakeholders in member States of West Africa cannot be overemphasized as this will enhance its production to attain global standard. It has been observed that high capacity of organic stakeholders in developed countries could have contributed to high production of organic foods, hence, the need to assess the operational capacity of stakeholders in West Africa.

Despite the fast growing technology that supports sustainable agriculture in West Africa, the need to look into the operational capacity gap among stakeholders of organic and agroecological agriculture in West Africa is imperative for the growth of sector and resultant benefits of food security. Therefore, this survey assessed the operational capacity gaps of stakeholders in organic and ecological agriculture in West Africa.

Background Information

Geography and Population of West Africa

West Africa is an imagined north–south axis lying close to 10° east longitude. The Atlantic Ocean forms the western as well as the southern borders of the West African region .The northern border is the Sahara Desert, with the Ranishanu Bend generally considered the northernmost part of the region. The eastern border is less precise, with some placing it at the Benue Trough, and others on a line running from Mount Cameroon to Lake Chad.

West Africa is comprised of 15 countries; Benin, Burkina Faso, Cape Verde, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo. The population of West Africa as at 2021 is estimated at about 412,453,951 (United Nations, 2021).

Organic Agriculture

The IFOAM Organics International (IFOAM, 2005) defines Organic agriculture has a holistic production management system which enhances agro-ecosystem health, utilizing both traditional and scientific knowledge. Organic agricultural system relies on ecosystem management rather than external agricultural inputs (IFOAM-Organics International, 2005). It is a production system that maintains soil health, ecosystems, and humans. Organic farming can be defined as "an approach to agriculture which aims at social, environmental and economic sustainability as well as animal welfare by minimizing the use of external resources, maximizing the use of locally-derived renewable resources and agro-ecosystem management" (Adenle *et al*., 2018). It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovations and science to benefit the shared environment and promote fair relationships as well as a good quality of life for all involved. The goal of organic farming is to give priority to long-term ecological health, such as biodiversity and soil quality, rather than short-term productivity gains (IFOAM, 2006).

Principles of Organic Agriculture by IFOAM Organics International

Basic principles guiding the organic agriculture include the following:

Principle of health: Organic agriculture should sustain and enhance the health of soils, plants, animals, humans and ecosystems in a way that takes into account the entirety and interrelationships of these systems; it is a holistic approach to farming.

Principle of ecology: Organic agriculture should be based on ecological systems this production is to be based on ecological processes already present in a given ecosystem, and the recycling of elements within the system.

Principle of fairness: Organic agriculture builds on relationships that ensure fairness with regard to the common environment as well as livelihood opportunities. Fairness is meant to apply to all levels and to all parties – farmers, workers, processors, distributors, traders and consumers.

Principle of care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Growth and Structure of Organic Agriculture

Globally, Oceania has the highest organic agricultural land of about [49.6%] of the world Organic Agricultural land, followed by Europe (22.9%) and Latin America [11.5%.] Africa has the least organic agricultural land in the world (2.8%) (FiBL. 2021).

Organic Agriculture has grown over the years in Africa with Tunisia topping the list in 2018, as compared with Tanzania in 2017 and Uganda in 2016. Sao Tome and Principe had a total land area of 24.9% for organic agriculture in Africa in 2019, followed by Sierra Leone (4.0%) and France (3.1%). Scientific and technical studies on organic agriculture are uncommon in Africa (De Bon et al., 2018).Official statistics in Africa contain little data on organic agriculture, even though its products are increasingly available on local and export markets. African consumers' demand is growing, providing a dynamic economic opportunity.

Table 1: Organic agricultural land (including in-conversion area and regions' share of the global organic agricultural land

Region	Organic Agricultural land (hectares)	Regions' shares of the global Organic agricultural land (%)
Oceania	35,881,053	49.6%
Europe	16,528,677	22.9%
Latin America	8,292,139	11.5%
Asia	5,911,622	8.2%
Northern America	3,647,623	5.0%
Africa	2,030,830	2.8%
WORLD	72,285,656	100%

Source: FiBL 2021

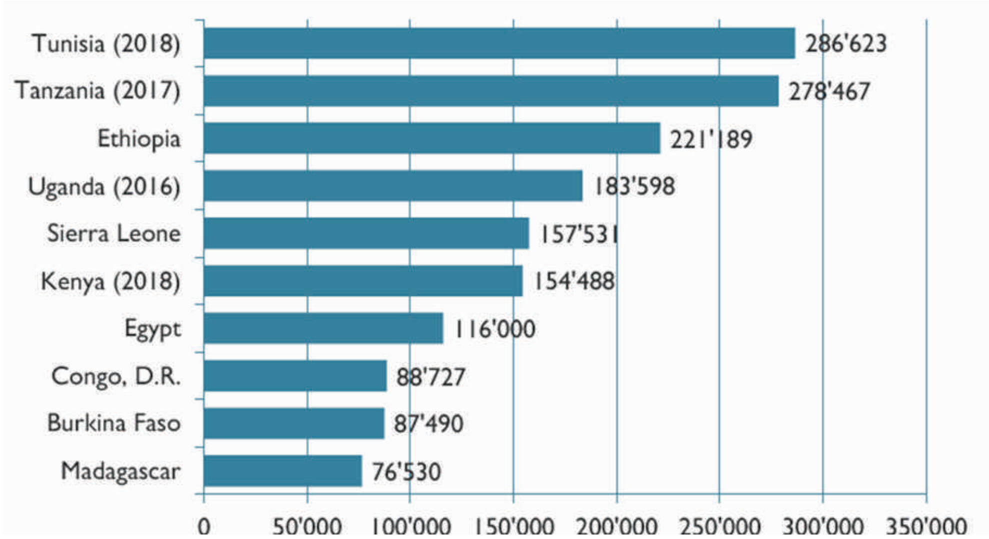

Figure 1: Organic Agriculture land area in Africa/
Source: FiBL, 2021

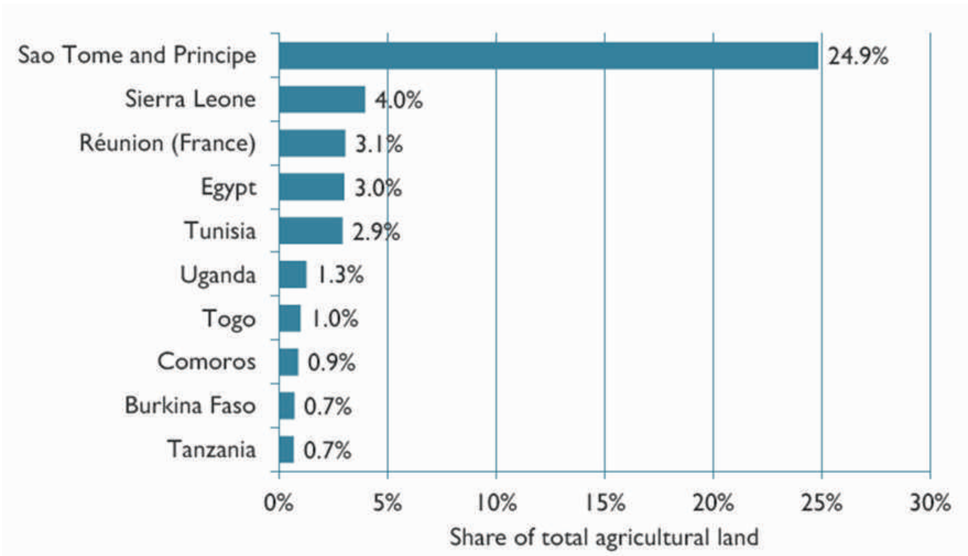

Figure 2: African countries with the highest organic share of total agricultural land in 2019
Source: FiBL 2021

The development of organic agriculture in West Africa is still low despite its potential of legitimately contributing to the goal of developing West African agriculture for national and regional markets. There has been a significant increase in the organic agricultural land in West Africa except for countries like Cape Verde and Liberia; Guinea Bissau dropped from 835 to 781 (FiBL, 2021). Sierra Leone had the highest number of organic agriculture land followed by Cote d'Ivoire and Nigeria in West Africa while Togo, Burkina Faso and Senegal have the highest number of producers. Although West Africa countries are gradually adopting organic agriculture the land area in respect to the total agricultural land is less than one percent. As regards information about producers in many West African countries more is available. There is no information about producers in many West Africa countries.

Table 2: Structure of organic farming in West Africa

Country	Organic Area (ha)	Share of organic area in total agricultural land (%)	Number of producers
Benin	16,454	0.4	030
Burkina Faso	56,663	0.7	26,627
Cape Verde	495	0.6	NA
Cote dỉvoire	50,574	0.2	2776
Gambia	20	0.003	NA
Ghana	29,663	0.2	3,228
Guinea	10	0.0001	NA
Guinea - Bissau	835	0.1	NA
Liberia	2.0	0.0001	NA
Mali	12,655	0.03	12,272
Niger	254	0.0012	NA
Nigeria	57,117	0.1	1,091
Senegal	7,989	0.1	18,369
Sierra Leone	99,238	2.5	304
Togo	41,323	1.0	38,414
Mauritania	NA	NA	NA

Source: FiBL 2021

Despite the increase in the number of organic producers in Africa (FIBL, 2021), adoption of organic agriculture in West Africa is still very low, due to information need of stakeholders in organic agriculture. Available information and the sources of such information have been one of the critical factors affecting adoption rates of innovations among farmers (IFOAM, 2003). Wheeler (2007) noted that organic farmers have often complained about inadequate knowledge of organic farming.

Materials and Methods

Study Area

A structured questionnaire targeted at capacity operational gap of organic agriculture was used to collect information from organic agriculture stakeholders in West Africa. The questionnaire was made available for distribution in all the West African countries (Figure 1); Nigeria, Benin, Burkina Faso, the island nation of Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Niger, Senegal, Sierra Leone and Togo. The study area which occupies an area is approximately one-fifth of Africa. It has a population of 412,453,951 according to the United Nations estimates (2021).

Plate 1: Map showing Countries in West Africa
Source: Encyclopedia Britannica, 2017

Population of the study

The respondents were organic practitioners in West Africa. It is to be noted that Cameroon, Chad and Mauritania are not in the Economic Community of West African States (ECOWAS)

Research Approach

The study made use of quantitative tools to obtain information from respondents via a structured questionnaire.

Period of study: June-October 2021

Measurement of variables

Data for the survey included respondents' personal stakeholders' category, means of accessing ecological /organic agriculture information, years of experience in organic/ ecological agriculture and operational capacity gaps.

Data Analysis

Data collected through the e-questionnaire were sorted and cleaned, coded and analysed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive analysis included charts, percentage, mean and weighted scores.

Results and Discussions

A) *Stakeholders of Organic Agriculture in West Africa*

Nine out of the sixteen countries in West Africa were sampled with a total number of 214 stakeholders. The nine countries include; Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Mali, Nigeria and Togo. There are 12 organic agriculture categories of operations highlighted among stakeholders in West Africa they are; Education, Technical partners, Researchers, Media, Extension service providers, Farmers, Consumers, Civil societies, Processors, Input producers, Policy makers and Marketers.

B) *Country Representation of Organic and Ecological Agriculture Stakeholders in West Africa*

Figure 3 reveals the number of countries represented in the survey Nine (9) out of the 16 countries in West Africa participated in the survey. The countries are Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Mali, Nigeria and Togo. No respondents were recorded in The Island nation of Cape Verde, Senegal, Sierra Leone, Guinea Bissau, Ivory Coast, Liberia and Niger. Nigeria had the highest number of respondents (55.78%) followed by Togo (16. 35 %), Benin (12. 15%), Ghana (5.14%) and Mali (3.24%) respectively. Burkina Faso and Gambia had the same number of respondent (3.27%) likewise Côte d'Ivoire and Guinea (0.40 %).

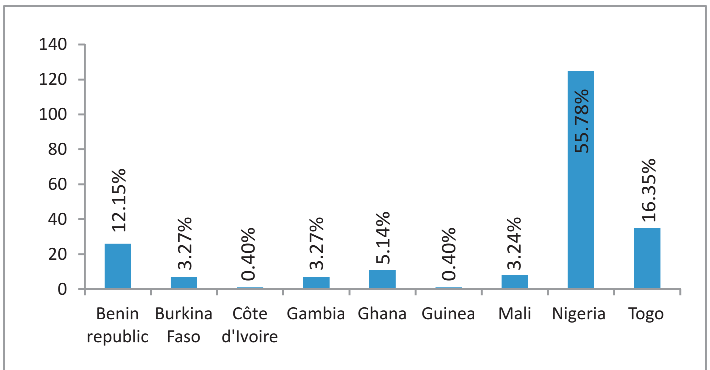

Figure 3: Distribution of Stakeholders of Organic Agriculture in West Africa

C) ***Means of accessing Organic and Ecological Agricultural Information***

Five (5) major means of accessing organic and ecological agriculture. information by the stakeholders were identified in the study. Majority of the stakeholders obtained information on Organic Agriculture. Figure 4 shows that (87.1%) of obtained stakeholders get information from the O.A. organization body while (3.6 %) access information via social media, (6.9%) through internet. (4.6%) through research and PGS and (3.2%) has access to O.A. information through government agency.

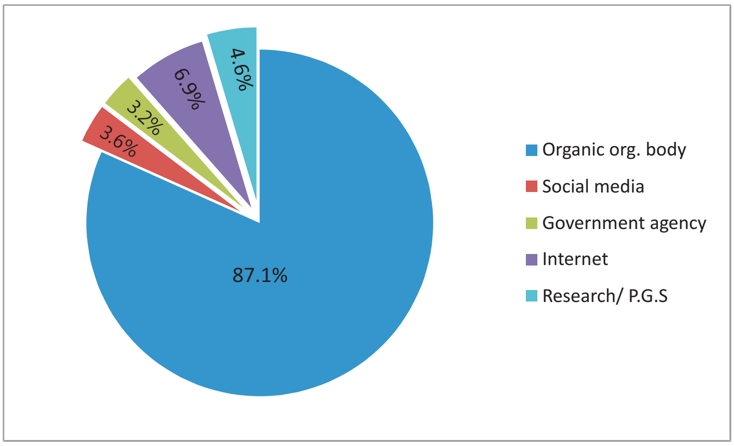

Figure 4: Means of accessing Organic Agriculture Information

D) ***Years of Experience in Organic Agriculture***

Many of the stakeholders are still new in Organic and Ecological Agriculture. Almost half of the stakeholders' years of experience spanned between 0 and 5 years (47.7%), followed by stakeholders with 6-10 years' experience (24.8%). Those with 11- 15 years of experience are (18.2%) while 16 and above is (4.7%).

E) ***Categories of Operation in Organic and Ecological Agriculture***

Figure 6 establishes that the stakeholders were in twelve (12) categories of operation. This includes Education/training, Technical Partners, Researchers, Media practitioners, Extension service providers, Farmers, Consumers, Civil society organizations, Processors, Input Producers, Policy makers and Marketers. Nigeria recorded the highest number of stakeholders' involvement in all categories of operation.

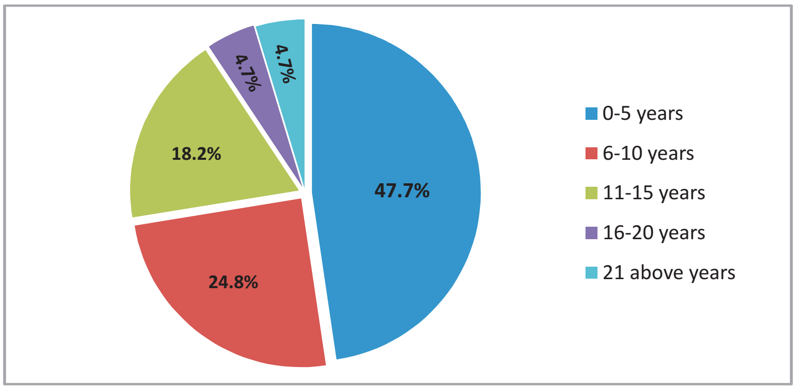

Figure 5: Distribution of years of experience in Organic and Ecological Agriculture Stakeholders in West Africa

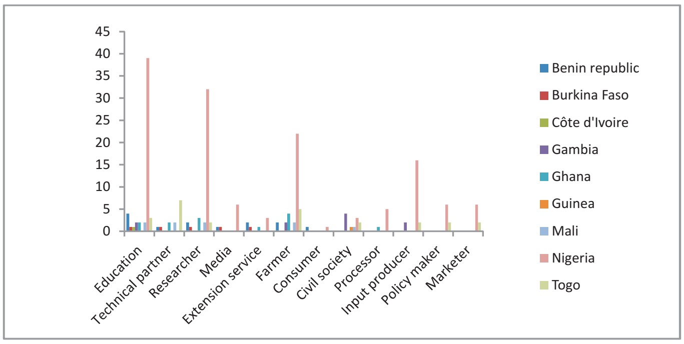

Figure 6: Category of Operation of Stakeholder in Organic Agriculture in West Africa

F) *Distribution of Organic Agriculture Stakeholders by Category*

Education and Training: the survey revealed that 31.2% of the stakeholders from Nigeria were involved in education and training of people in organic agriculture, while 15.4% of the stakeholders from Benin and 14.3% of stakeholders from Burkina Faso were also involved in education and training. No respondent from Guinea is involved in education and training.

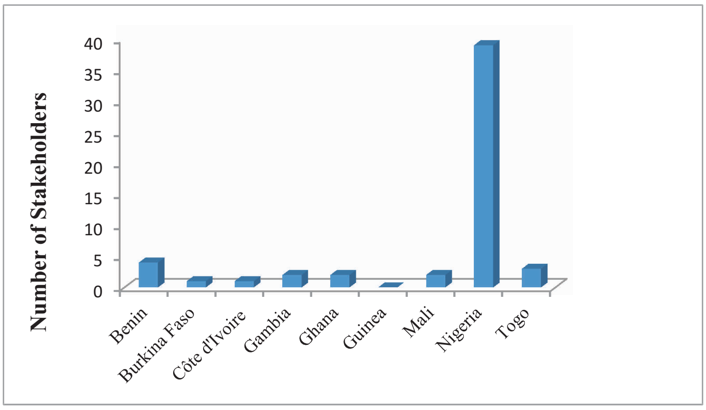

Figure 7: Distribution of Stakeholders involved in Education of Organic Agriculture in West Africa

Technical Partners: Majority of the stakeholders who were technical partners are from Mali (25%), closely followed by Togo (20%) and Ghana (18.2%). However, Nigeria, Guinea, Gambia and Cot d' Ivore do not have any stakeholder as technical partners, according to the findings of the survey.

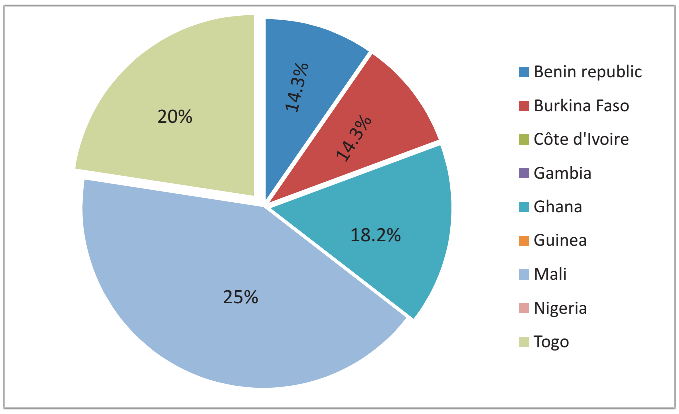

Figure 8: Distribution of Stakeholders involved in Technical partners of Organic Agriculture in West Africa

Researchers: Five (5) out of the nine (9) countries had stakeholders that are involved in organic agricultural research. 27.3% of Ghana stakeholders were researchers while 25.6% of stakeholders in Nigeria and 25% of Mali were involved in organic agricultural research. 14.3% of stakeholders from Burkina Faso, 7.7% from Benin and 5.7% from Togo were also involved in research on organic agriculture. No researcher from Cote d' lvoire, Gambia and Guinea was captured in the survey.

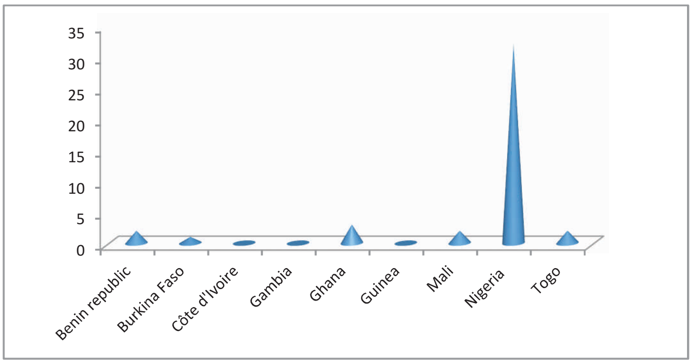

Figure 9: Distribution of Stakeholders involved as Researchers of Organic Agriculture in West Africa

Media and Extension Service: Benin, Burkina Faso, Ghana and Nigeria were the only countries with stakeholders involved in Media and Extension Service. 14.3% of stakeholders in Burkina Faso were into both Media and Extension Service. 9.1% of Ghana stakeholders were into Extension Service while 4.8% of stakeholders from Nigeria were involve in Media practitioners.

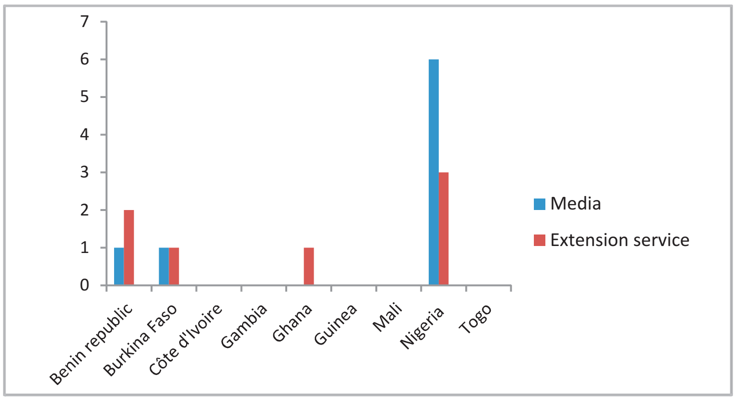

Figure 10: Distribution of Stakeholders involved as Media and Extension Service of Organic Agriculture in West Africa

Farmers: Nigeria recorded the highest number of stakeholders involved in organic farming, followed by Togo and Ghana. Benin, Gambia and Mali had the same number of stakeholders involved in organic farming.

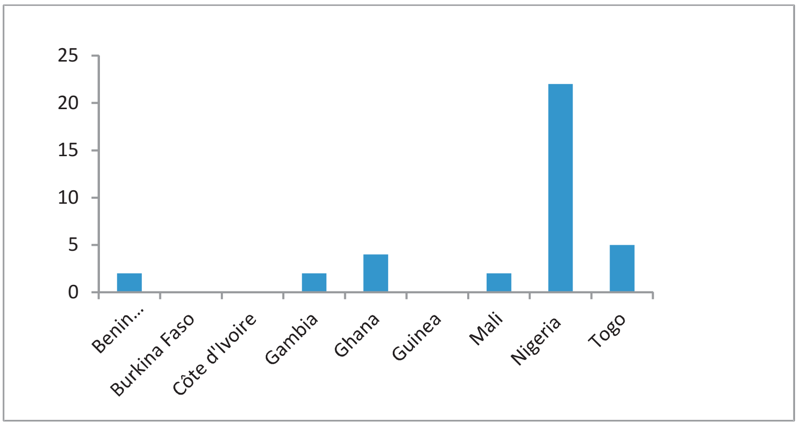

Figure 11: Distribution of Stakeholders involved in Organic farming in West Africa

Input producers, Policy makers and Marketers: Three (3) out of the nine (9) countries captured were involved in input production; these are Gambia, Nigeria and Togo. Nigeria had the highest number of stakeholders involved in input production, as revealed in Fig 12. Stakeholders from Nigeria and Togo were also involved in policy making and marketing of organic produce. 4.8% of stakeholders from Nigeria were into both policy making and marketing, while 5.7% of stakeholders from Togo were involved in policy making and 8.6% were into marketing of organic produce.

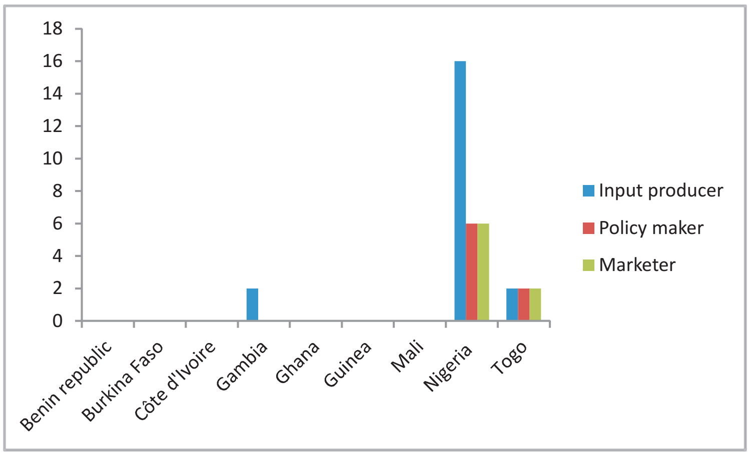

Figure 12: Distribution of Stakeholders involved in Input production, Policy making and Marketing in West Africa

G) ***Identification and Ranking of Capacity Operational Gaps***

The operational capacity gaps identified are in the following order: Unavailability of organic inputs (76) > Lack of information on organic agriculture (61) > Insufficient funds for organic agriculture (59) > Inaccessibility to organic market (50) > Improper pest and disease management (43) > Inadequate training (42) and Advocacy of organic agriculture (42) > Poor Government policy on organic and ecological agriculture (41) and Lack of modern equipment (41) and > Unaffordability of organic input (27) > High cost of certification (25) > Poor research on organic agriculture (23) > Lack of organic agriculture technical personnel/extension agent (17) > Improper networking among organic organization body in West Africa (14) > Inadequate processing, storage and value addition chain (12) as well as Improper soil management for organic farming (12).

Table 3: Ranking of Capacity Operational Gaps

Rank	Capacity Operational Gap	Respondents
1st	Unavailability of organic input	76
2nd	Lack of information/ awareness on organic and ecological agriculture	61
3rd	Lack of funds	59
4th	Inaccessibility of organic market	50
5th	Improper pest and diseases management	43
6th	Inadequate training	42
6th	Advocacy of organic agriculture	42
7th	Lack of provision of modern equipment for large scale farming	41
7th	Poor government policy on organic and ecological agriculture	41
8th	Unaffordability of organic input	27
9th	High cost of certification	25
10th	Poor research on organic ecological agriculture	23
11th	Lack of organic agriculture technical personnel/extension agent	17
12th	Improper networking among organic and ecological organizational bodies in West Africa	14
13th	Inadequate processing, storage and value addition chain	12
13th	Improper soil management for organic farming	12

Table 4: Highlighted Operational Capacity Gaps and Possible Solutions

S/N	Highlighted Operational Capacity Gap	Possible Solutions
1	Unavailability of organic input	Governments of different countries need to drive the process of indigenous industrial development in the production of organic input
2	Lack of information/ awareness on organicand ecological agriculture	There should be an information hub that is accessible to all stakeholders in Organic and Ecological Agriculture
3	Lack of funds	Government should provide funds in form of loans and/or provide guarantee to organic farmers in commercial banks to obtain loans to increase their production. National and international organizations that encourage the development of organicand ecological agriculture for sustainable development should also provide funds to farmers in West Africa.
4	Inaccessibility of organic and ecological market	
5	Improper pests and diseases management	Creation of marketing channels to sell produce without much constraint is imperative
6	Lack of adequate training	Organic pesticide should be made available at subsidized rate for organic farmers
7	Advocacy of organic and ecological agriculture	Continuous training should be conducted by organic organization/ technical personnel for stakeholders
		International development agencies

S/N	Highlighted Operational Capacity Gap	Possible Solutions
		and NGOs will play a significant role in advocacy and awareness creation on the need to embrace organic and ecological agriculture
8	Lack of provision of modern equipment for large scale farming	The useof better technologies for expanding cultivated land in organic and ecological agriculture
9	Poor government policy on organic and ecological agriculture	Policy guidelines and instruments addressing training and education of farmers will enhance the development and proliferation of organicand ecological agriculture in West Africa
10	Unaffordability of organic input	Organic input should be subsidized for poor farmers willing to embrace Organic Agriculture
11	High cost of certification	Certification cost should be reduced to allow organic farmers participate
12	Poor research on organic agriculture	Funding of organic and ecological agriculture research and development will be crucial to the success of organic farming
13	Lack of organic agriculture technical personnel/ extension agent	Adoption of Organic Agriculture will increase when extension agents

Summary

Only nine out of the 16 West African countries participated in the survey. They include; Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Mali, Nigeria and Togo. A total of 214 stakeholders were captured. The sturdy highlighted twelve organic agriculture categories of operations among stakeholders in West Africa. These include; Education, Technical partners, Researchers, Media practitioners, Extension service producers, Farmers, Consumers, civil society organization, Processors, Input producers, Policy makers and Marketers.

The survey revealed more male gender participation in organic and ecological agriculture in West Africa. Majority of the stakeholders had access to information through the organic agricultural networks. More than half of the stakeholders had less than ten years' experience in organic and ecological agriculture. Majority of the stakeholders belong to the education and technical partners' categories.

Majority of the respondents identified unavailability of organic inputs as a major component of capacity operational gaps of stakeholders in organic and ecological system. Lack of information and insufficient funds were also identified as a major catalyst in capacity operational gaps of stakeholders.

Conclusion

This study identified sixteen (16) major capacity gaps of stakeholders of organic and ecological agriculture in West Africa. Development of Organic and Ecological Agriculture in West Africa could be enhanced if adequate attention is paid to capacity gaps of the stakeholders.

Recommendation

* Attention of appropriate authorities and development bodies should be directed to identify capacity gaps among stakeholders of organic and ecological agriculture in West Africa.
* The ECOWAS Commission and member states should incorporate capacity building on organic and ecological agriculture into agriculture investment plans.
* Priority should be given to the identified gaps in the order of ranking in this study.
* There should be periodic assessment on the progress of intervention at least on a five-year basis.

Acknowledgements

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Aqueous Extract of *Commelina benghalensis* L. as an Alternative Herbicide for the control of weeds in Okra (*Abelmoschus esculentus* L. Moench) Production

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Keywords:
Commelina benghalensis, Bio-herbicide, Relative Importance Value, Okra, Organic Agriculture, Food quality and Safety

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Abstract

This study focused on the bio-herbicidal potential of *Commelina benghalensis* in controlling weeds in okra production. Shoot and leaf parts of *C. benghalensis* were harvested and dried at ambient room temperature for two weeks. The dried parts were milled separately into fine powders and were taken to the Analytical Laboratory for phytochemical analysis using standard procedures. Extracts from the powdered shoot and leaf parts of *C. benghalensis* were prepared separately and in-combination by soaking 200 g in 1000 mL of water for three days. Concentration of the stock solution of the bio-herbicide was 100%, while 50% concentration was prepared from it by serial dilution. Glyphosate was prepared into recommended rate (5.31 mL in 500 mL of water) and half recommended (2.66 mL in 500 mL of water) and 2.66 mL in 500 mL of water + 50% of leaf and shoot of *C. bengalensis* extract). Eight treatments used in the study were: T1- Glyphosate Recommended rate, T2- Control (Weedy check), T3- 100% (Leaf +Shoot), T4 - 50% (Leaf +Shoot), T5-100% (Leaf extract), T6- 50% (Leaf extract), T7- Glyphosate half of recommended rate, T8- Glyphosate (half of recommended rate + 50% Leaf + Shoot extract). Treatments were replicated three times and laid in a randomised complete block design on the field and applied as pre-emergent herbicides. Weed biodiversity (Relative Importance Value (RIV)) was taken on the experimental field using a quadrat ($0.5m^2$); before (Day 0) application and at 15, 30 45 days after treatment (DAT). Okra seeds (NHAe-47-4) were sown and later thinned to a plant/stand. Data collected were on plant height (PH), number of leaves (NOL), stem diameter (SD), number of fruits (NOF) and fresh fruit weight (FFW) (yield) and analysed using ANOVA $p<0.05$. Results of phytochemical analysis on leaf part of *C. benghalensis* revealed significant higher phenolic, flavonoid and terpenoid compounds than the shoot part. Significant higher PH (14.87, 26.71 and 43.36 cm) and SD (2.57, 3.45 and 7.31 mm) were obtained at 4, 6 and 8 weeks after sowing, respectively from T3. Treatments (T1 and T6) had the lowest PH (10.37, 16.53 and 26.76 cm) and SD (1.82, 3.09 and 4.54 mm). Highest values (12.67; 12.33) of NOF were from T5 and T7, respectively and FFW (20.37; 23.94 g) from T4 and T7, respectively, while lowest values 7.33 and 9.37 g were from T2 and T6, respectively. Significant reduction in RIV (2.33-10.51 and 1.52-17.51) was observed at 15 and 30 DAT, respectively from all the extracts and glyphosate, while T8 was able to able to suppress weeds till 45 DAT (2.71-22.11).This study revealed that, the growth and yield parameters of okra were enhanced from aqueous extract at 100% (leaf +shoot), 100% (leaf), while

Glyphosate half recommended + 50% (leaf and shoot) suppressed weeds from 15 till 45 Days After Treatment when the okra could have survived its critical weed interference. *Commelina benghalensis* aqueous extract therefore, could serve as a bio-herbicide in improving okra crop yield and suppressing weed growth in Organic Agriculture for food sustainability, food quality and safety.

Extrait aqueux de Commelina benghalensis L. comme herbicide alternatif pour le contrôle des mauvaises herbes dans la production de gombo (*Abelmoschus esculentus L. Moench*)

Résumé

Cette étude s'est concentrée sur le potentiel bio-herbicide de Commelina benghalensis dans le contrôle des mauvaises herbes dans la production de gombo. Les parties des pousses et des feuilles de C. benghalensis ont été récoltées et séchées à température ambiante pendant deux semaines. Les parties séchées ont été moulues séparément en poudres fines et ont été transportées au laboratoire d'analyse pour l'analyse phytochimique en utilisant des procédures standard. Des extraits de la poudre de pousses et de feuilles de C. benghalensis ont été préparés séparément et en combinaison en faisant tremper 200 g dans 1000 ml d'eau pendant trois jours. La concentration de la solution mère du bio-herbicide était de 100%, tandis qu'une concentration de 50% a été préparée à partir de celle-ci par dilution en série. Le glyphosate a été préparé au taux recommandé (5,31 mL dans 500 mL d'eau) et à la moitié du taux recommandé (2,66 mL dans 500 mL d'eau) et 2,66 mL dans 500 mL d'eau + 50 % d'extrait de feuilles et de pousses de C. bengalensis). Les huit traitements utilisés dans l'étude étaient les suivants T1- Glyphosate taux recommandé, T2- Contrôle (Weedy check), T3- 100% (feuille + pousse), T4- 50% (feuille + pousse), T5- 100% (extrait de feuille), T6- 50% (extrait de feuille), T7- Glyphosate moitié du taux recommandé, T8- Glyphosate (moitié du taux recommandé + 50% extrait de feuille + pousse). Les traitements ont été répliqués trois fois et disposés dans un plan en blocs complets randomisés sur le terrain et appliqués comme herbicides de pré-levée. La biodiversité des mauvaises herbes (valeur d'importance relative (VIR)) a été mesurée sur le champ expérimental à l'aide d'un quadrat (0,5 m2), avant l'application (jour 0) et 15, 30 et 45 jours après le traitement (DAT). Les graines de gombo (NHAe-47-4) ont été semées puis éclaircies jusqu'à l'obtention d'une plante/support. Les données recueillies concernent la hauteur des plantes (PH), le nombre de feuilles (NOL), le diamètre des tiges (SD), le nombre de fruits (NOF) et le poids des fruits frais (FFW) (rendement) et ont été analysées en utilisant ANOVA p<0,05. Les résultats de l'analyse phytochimique de la partie foliaire de C. benghalensis ont révélé des composés phénoliques, flavonoïdes et terpénoïdes significativement plus élevés que ceux de la partie pousse. Des PH (14,87, 26,71 et 43,36 cm) et SD (2,57, 3,45 et 7,31 mm) significativement plus élevés ont été obtenus à 4, 6 et 8 semaines après le semis, respectivement à partir de T3. Les traitements (T1 et T6) avaient le PH (10,37, 16,53 et 26,76 cm) et le SD (1,82, 3,09 et 4,54 mm) les plus bas. Les valeurs les plus élevées (12,67 ; 12,33) de NOF provenaient de T5 et T7, respectivement, et de FFW (20,37 ; 23,94 g) de T4 et T7, respectivement, tandis que les valeurs les plus faibles (7,33 et 9,37 g) provenaient de T2 et T6, respectivement. Une réduction significative du RIV (2,33-10,51 et 1,52-17,51) a été observée à 15 et 30 DAT, respectivement pour tous les extraits et le glyphosate, tandis que T8 a été capable de supprimer les mauvaises

Mots – clés:
Commelina benghalensis,
bio-herbicide,
valeur d'importance relative,
gombo, agriculture biologique, qualité et sécurité alimentaire.

herbes jusqu'à 45 DAT (2,71-22,11). Cette étude a révélé que les paramètres de croissance et de rendement du gombo ont été améliorés par l'extrait aqueux à 100% (feuille + pousse), 100% (feuille), tandis que le glyphosate à moitié recommandé + 50% (feuille et pousse) a supprimé les mauvaises herbes de 15 à 45 jours après le traitement, lorsque le gombo aurait pu survivre à l'interférence critique des mauvaises herbes. L'extrait aqueux de Commelina benghalensis pourrait donc servir de bio-herbicide pour améliorer le rendement des cultures de gombo et supprimer la croissance des mauvaises herbes dans l'agriculture biologique pour la durabilité, la qualité et la sécurité alimentaires.

Introduction

Agrochemicals, such as herbicides, fungicides, insecticides and nematicides, have been used intensively in agriculture for increasing population. Overuse of synthetic agrochemicals causes environmental hazards, nutrients deficiency, global degradation of soil properties (Chou *et al*., 2010) ill health or death to users and extinct of biodiversity of plants and animals in the ecosystem. However, reports had revealed the discovery of other useful natural chemical products in the last decade (Dayan *et al.,* 2009). Allelopathy is the process whereby plants or with plant-microorganisms' interactions release compounds to either stimulate or inhibit the growth of other plants growing; in the same habitat in natural and agricultural ecosystem (Duke *et al*., 2002), which can play an eco-friendly role in weed management. Use of allelochemicals involved in allelopathic interactions between plants could satisfy the requirements for weeds` management and crop protection (Singh *et al*., 2003) and most importantly strategies for herbicide discovery. Some plants exhibit allelopathic effects on seed germination and development of other plants by releasing secondary metabolites into the soil, either as exudates from living organs or by plant residues decomposition (Scrivanti *et al*., 2010).

Some studies carried out by earlier researchers have revealed and explored the inhibitory potential of different allelopathic crops and trees for weed management (Cheema *et al.,* 2004; Farooq *et al.,* 2011). This is a pragmatic substitute of synthetic herbicides as allelochemicals do not have residual or toxic effects due to their short half-life and are considered safe of environmental toxicology view point (Duke *et al*, 2002). Reduction in weed biomass and increase in wheat yield was observed by the application of sorghum (*Sorghum bicolor* L.) water extracts (Cheema *et al*., 2003). Fayinminnu *et al*. (2013) reported that crude cassava water extract enhanced growth and yield of cowpea but suppressed and markedly reduced weeds of cowpea. Also it has been studied that Eucalyptus aqueous extract inhibited weeds` growth in cowpea field and enhanced the grain yield (Isienyin *et al*., 2020). Extracts of many plant species can be successfully used as bio- herbicide (Dayan, 2002; Singh *et al*., 2005) and thus the herbicides use could be reduced by combining the allelopathic water extracts with lower doses of synthetic herbicides (Jabran *et al*., 2012) for a long season control of weeds.

Aqueous extracts have been used as potential herbicides in mixture with reduced dose of chemical herbicides (Cheema *et al.,* 2012). Allelopathic aqueous extracts have reduced herbicide doses by half of standard giving effective control over noxious weeds of major crops (Cheema *et al.,* 2003); they have effective results in controlling weeds by reducing herbicide dose up to half of recommended one. In this way allelochemicals can control weeds to reduce weed-crop competition and to enhance crop growth and yield.

Okra *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world, (FAOSTAT, 2008). It provides an important source of vitamins, calcium, potassium and other mineral matters (Moyin-Jesu, 2007) which are often lacking in the diet of many developing countries. Okra is prone to infestation by various weeds which can serve as major constraints to its production if not properly controlled (Adejonwo *et al*., 1989). There is therefore the need to maintain weed interference in Okra from 2 to 8 weeks after sowing in order to avoid yield loss >10% (Awodoyin and Olubode, 2009). Synthetic herbicides commonly used to reduce weed population in okra field include centrazone (Aim), glyphosate (Roundup) and paraquat (Gramozone Inteon).

Glyphosate is effective in killing a wide variety of plants, including grasses and broadleaf and woody plants. By volume, it is one of the most widely used herbicides (Mosanto, 2010). Glyphosate (*N*-(phosphonomethyl) glycine) is an organophosphorus compound, broad-spectrum systemic herbicide and crop desiccant. It is effective in controlling a wide variety of plants, including grasses, annual broad-leaf weeds and woody plants that compete with crops. By volume, glyphosate is one of the most widely used herbicides (Henderson *et al*., 2010). In 2007, glyphosate was the most used herbicide in the United States agricultural sector, with 180 to 185 million pounds (82,000 to 84,000 tonnes) applied. Also the second-most used in home and garden with 5 to 8 million pounds (2,300 to 3,600 tonnes) and government applied 13 to 15 million pounds (5,900 to 6,800 tonnes) in industry and commerce (USEPA, 2007). It is commonly used for agriculture, horticulture, viticulture and silviculture purposes, as well as garden maintenance.

Commelina benghalensis (Tropical spiderwort or Benghal dayflower) belongs to the family Commelinaceae. It has become increasingly important in agronomic production systems in the south-eastern coastal plain of the United States of America (USA). This weed was listed as a Federal Noxious weed in Florida and Georgia where it is the most troublesome weed in cotton and a pest in peanut, corn (*Zea mays*), soybean (*Glycine max*) and rice (*Oryza sativa*) (Caton *et al*., 2004). *Commelina* species both annuals and perennials dominate the fallow vegetation because they are most competitive due to their growth and regeneration characteristics. The plant is propagated mainly by seeds, stem cuttings and rooting from nodes and pieces. *Commelina benghalensis* is the most important of the three and it occurs as a weed in 25 different crops in 28 countries (Webstar *et al*., 2005). *Commelina* specie is a broadleaved weed which is generally not considered highly competitive for nutrients, however this fact is not well researched and its allelopathic potential also needs to be ascertained. Faden (1993) reported that invasive species such as *C. benghalensis* had higher plant growth rate at high nutrient availability. The plant is considered useful with benefits as a diuretic, febrifuge, anti-inflammatory and laxative (Hong and Defillipps, 2000). Many species of *Commelina* are edible by humans and livestock through steaming. The young stems of *C. diffusa* are eaten as a vegetable by Javans in India (Hong and DeFllips, 2000). Rezendes *et al*. (2020) however, recorded increased reduction in the root development and radicle length of lettuce (*Lactuca sativa*) seedlings with 75 and 100% extracts concentration of *C. benghalensis* suggesting its allelopathic potential.

Synthetic herbicides have proven to be effective in the control of weeds of arable crops; however, the use of synthetic pesticides is being discouraged because of their adverse health and environmental effects (Fayinminnu *et al*., 2013). With the continuing, increasing occurrence of herbicide-resistant weeds in agricultural systems, there is renewed interest in determining how/if bio - herbicides might be used as a possible option in weed control systems. Aqueous extracts have been used as potential herbicides in mixture with reduced dose of synthetic chemical herbicides (Cheema *et al.,* 2012). Allelopathic aqueous extracts have reduced herbicide doses by half of standard giving effective control over noxious weeds of major crops (Cheema *et al.,* 2003); they have effective results in controlling weeds by reducing herbicide dose up to half of recommended one. Also reduce weed-crop competition and thus enhanced crop growth and yield.

Therefore, the objectives of this study were (i) to determine the phytochemicals present in aqueous extracts of leaves and shoots of *Commelina benghalensis* (ii) to evaluate the efficacy of bio herbicidal effects of *Commelina benghalensis* aqueous extracts on the weeds, growth and yield of Okra.

Materials and Methods

Experimental materials

Commelina benghalensis plants were collected from the wild within the University of Ibadan, Nigeria, Glyphosate herbicide was purchased from SARO Agro Sciences Limited and Okra seeds NHAe-47-4 were purchased from National Horticulture Research Institute (NIHORT), Idi-Ishin all in Ibadan, Nigeria. Quantitative phytochemical analyses of the *C. benghalensis* plant parts were carried out at Femtop Analytical Laboratory, Idi-Ishin, Ibadan, Oyo State, Nigeria to determine the presence and quantity of secondary metabolites. *Commelina benghalensis* aqueous extracts and glyphosate rates were applied as pre-emergence on the field.

Preparation of *Commelina benghalensis* aqueous extracts

Fresh plants of *C. benghalensis* were harvested and separated into leaves and shoots and air dried at Toxicology Research Laboratory of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, Nigeria, for two weeks at average room temperature of 28.71± 1.77°C and relative humidity of 77.64 ± 8.07%. Each dried plant parts were milled separately using QASA Grinder Mixer into powder and weighed. Aqueous extract of the plant was obtained by soaking 200 grams of milled leaves and shoots in 1000 mL of water (ratio 1:5) for three days in order to remove the soluble allelochemicals. Concentration of the aqueous stock solution of *C. benghalensis* was 100%, while 50% was prepared from the stock solution by serial dilution. Glyphosate synthetic herbicide rates were prepared as following: Glyphosate recommended rate (5.31 mL in 500 mL of water) and half recommended (2.66 mL in 500 mL of water) and 2.66 mL in 500 mL of water + 50% of leaf and shoot of *C. bengalensis* extract.

Experimental Field Study

This was carried out at the Crop Garden of Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. The study site lies within latitude 7° 43"N and longitude 3° 54"E at an altitude of 200 m with annual rainfall between 1,250-1,500 mm spanning eight months (March-October) with dry spell in August; annual average temperature of 21.3°C and relative humidity of 70-80%. The aqueous extract of *C. benghalensis* and synthetic herbicide (Glyphosate) at different concentrations were used to manage okra weeds. Total and individual weed densities were recorded before clearing the plots/field for okra sowing, using quadrats measuring 0.5 m^2, Individual weed density was also recorded at intervals Day 15, 30 and 45, respectively. Identification of weed species was done using a hand book of West African weeds (Akobundu and Agyakwa, 1998).

The experiment was laid out in a randomised complete block design with three replications in plots measuring 10 m x 5 m with inter row and intra row spacing of 90 cm x 50 cm. Two okra seeds (NHAe-47-4) were sown in a hole at 2 mm depth. The treatments comprised of different combinations of *C. benghalensis* aqueous extracts and glyphosate: Eight treatments were used in the study: T1- Glyphosate Recommended rate, T2- Control (Weedy check), T3- 100% (Leaf +Shoot), T4 – 50% (Leaf +Shoot), T5-100% (Leaf extract), T6- 50% (Leaf extract), T7- Glyphosate half of recommended rate, T8- Glyphosate (half of recommended rate + 50% Leaf +Shoot extract). Treatments were applied as pre-emergent herbicides immediately after sowing using knapsack hand sprayer fitted with flat fan nozzle, while the missing stands of okra seedlings were supplied one week after sowing (WAS) and seedlings were later thinned to one seedling per stand at 2 WAS.

Data Collection and Analysis

Data on weed densities (Relative Importance Value (RIV)) were recorded with the help of quadrat measuring 0.50 x 0.50 m^2 randomly placed at two places in respective experimental units. Growth and yield parameters such as Plant height (PH), Number of leaves (NOL) and stem girth (SG), Number of fruits (NOF) per plant and Fresh fruit (FF) weights (yield) were also recorded. Data obtained were analysed using Analysis of Variance (ANOVA) and the treatments means were separated using Duncan Multiple Range Test at $p \leq 0.05$.

Results

Commelina benghalensis leaf samples contained more phytochemicals than the stem samples as shown in Table 1. Terpenoids, Alkaloids, Steroids and Anthraquinones were present in trace amounts in both leaf and stem samples. Saponin was present in trace amount in leaf sample, while it was absent/negligible in stem sample. Also, Glycoside's active ingredient had moderate amount in the leaf, while that of the stem was in trace amount. Flavonoid was moderate in the stem samples, while it was in appreciable amount in the leaf. However, the analysis revealed the same appreciable amount of Phenolics in both leaf and stem samples.

Table 1: Qualitative phytochemical analysis of different parts of Commelina benghalensis (mg/100mg)

	Samples	
	Leaf	Stem
Phenolics	+++	+++
Flavonoids	+++	++
Tannin	++	+
Saponin	+	-
Glycosides	++	+
Terpenoids	+	+
Alkaloids	+	+
Steroids	+	+
Antraquinone	+	+
Anthocyanin	-	-

Key: + = trace; + + = moderate amount; + + + = appreciable amount; - = absent or negligible

Quantitative phytochemical analysis of different parts of *Commelina benghalensis* (mg/100g)

Leaf samples of *Commelina benghalensis* contained more phytochemicals than the stem and with significant differences ($p < 0.05$) (Figs 1a-1c). Steroid in the leaf samples was 23.7 mg/100g, while the stem had 17.3 mg/100g. Highest value (37.6mg/100g) Anthraquinone was obtained from the leaf, while 36.3mg/100g was recorded from the stem. The leaf had a maximum value 59.1 mg/100g of Terpenoids, while the stem had 52.1 mg/100g as the minimum value. Saponin highest value 12.6 mg/100g was recorded in leaf, while the stem sample had the lowest value of 5.6mg/100g. Glycoside in the result showed leaf samples having 242 mg/100g, while the stem had 213 mg/100g. Maximum value of 553 mg/100g Tannin was present in the leaf sample, while the stem had 346 mg/100g minimum value. Phenolic in the leaf samples had the highest value (1536 mg/100g), while the stem had (1508 mg/100g) as the lowest value.

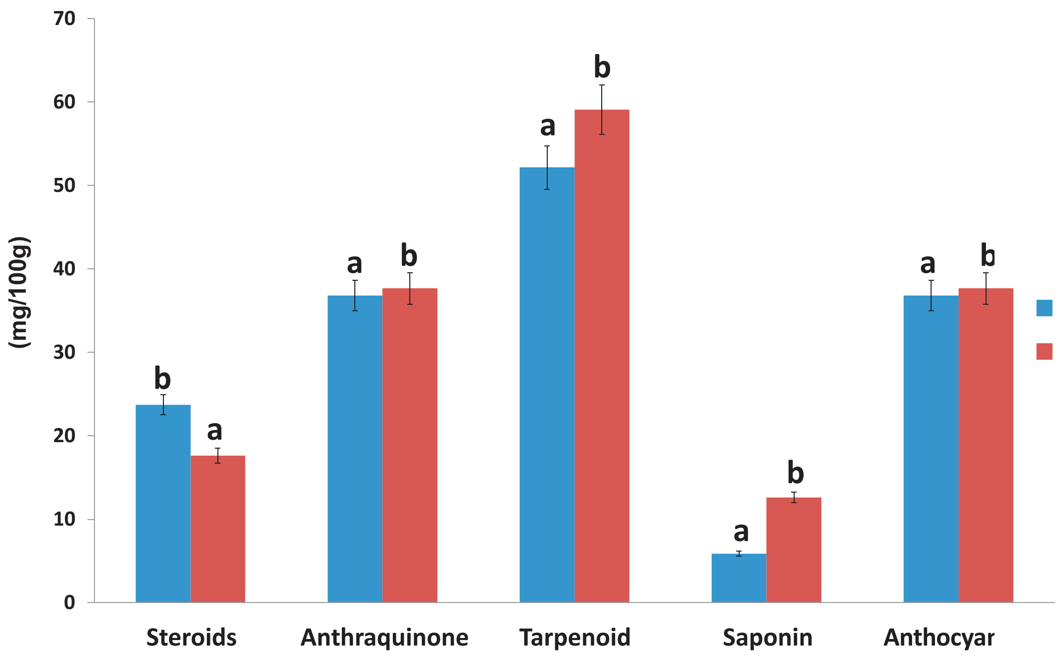

Figure 1: Phytochemical constituents of different parts of *C. benghalensis*
Bars followed by the same letters are not significantly different at p<0.05 using Duncan's Multiple Range Test

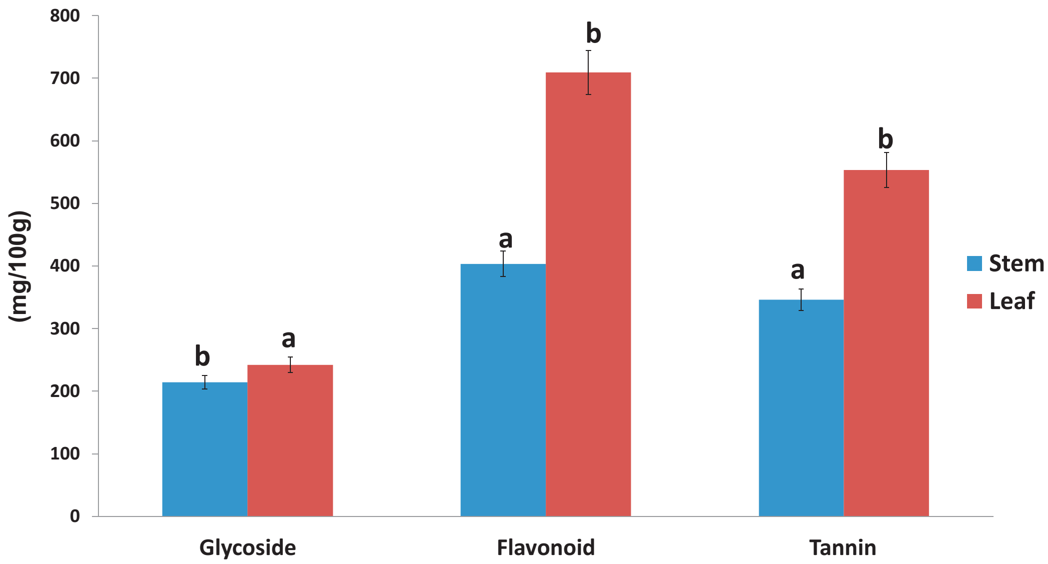

Figure 2: Glycoside, Flavonoid and Tannin constituents of different parts of *Commelina benghalensis*
Bars followed by the same letters are not significantly different at p<0.05 using Duncan's Multiple Range Test

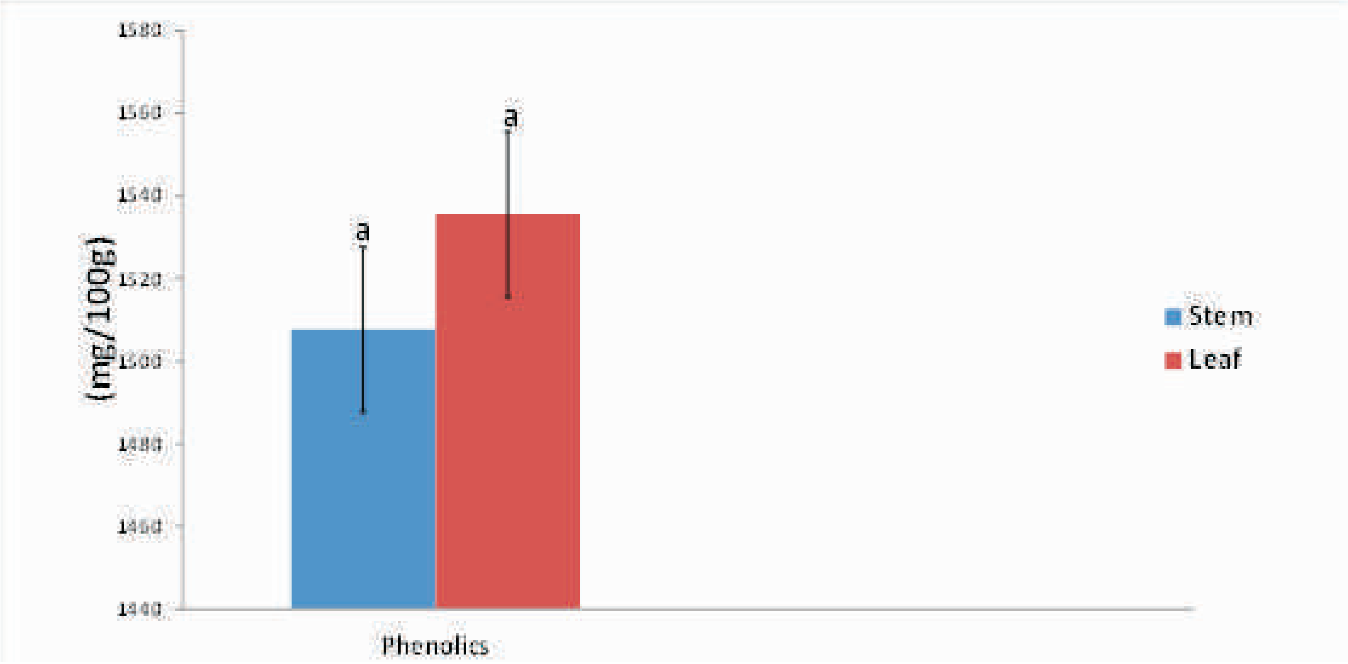

Figure 3: Phenolics constituents of different parts of *Commelina benghalensis*
Bars followed by the same letters are not significantly different at $p<0.05$ using Duncan's Multiple Range Test

Herbaceous composition and Relative Importance Value (RIV) of weeds flora at the experimental site before planting

Results on the herbaceous composition of weeds revealed a total of 10 weed species belonging to seven families enumerated on the experimental site before planting. Euphorbiaceae had the largest number species of three followed by Tiliaceae with two species, while Convolvulaceae, Nyctaginaceae, Portulacaceae, Poaceae and Commelinaceae had the lowest number of one species, respectively (Table 2). The Relative Importance Value (RIV) showed *Acalypha fibriata* having the highest RIV of 22.41, followed by *Boehavia diffusa* (RIV: 18.90) with lowest RIV 3.22 from *Trianthema portulaca* (Table 2).

Herbaceous composition and RIV of herbaceous weeds flora of the experimental site at 15, 30 and 45 days after treatment (DAT)

Composition of herbaceous weeds flora at 15 DAT showed a total of nine weed species belonging to seven families which were: Euphorbiaceae with highest three species, Tiliaceae having two species, while other families Nyctaginaceae, Portulacaceae, Poaceae and Commelinaceae had one specie, respectively (Table 2). The RIV revealed reduction in the population and density of the herbaceous weeds flora present at 15 DAT compared to Day 0 of herbicide treatment application (Table 2). Population of *Ipomea eriocarpa* reduced from 8.91 RIV at Day 0 to 0.0 RIV at 15 DAT. *Acalypha fibriata* had the highest RIV of 10.51, followed by *Boehavia diffusa* (RIV: 8.21), while *Trianthema portulaca* had the lowest RIV (2.33) (Table 2).

Results obtained at 30 DAT showed a total of 11 weed species belonging to seven families with Euphorbiaceae having four species as highest followed by Tiliaceae with two species. Convolvulaceae, Nyctaginaceae, Portulacaceae, Poaceae and Commelinaceae had one species, respectively (Table 2). There was reduction in RIV of the herbaceous weeds flora present at 30 DAT when compared to Day 0. However, there was an increase of *Ipomea eriocarpa* at 15 DAT from 0.0 RIV to 1.5 RIV at 30 DAT.

Acalypha fibriata had the highest RIV (17.51), lowest RIV (1.52) was recorded from *Ipomea erioarpa* (Table 2).

Herbaceous composition of weeds flora as presented on Table 2 revealed 11 weed species belonging to seven families at 45 DAT. However, results followed the same trend as in 30 DAT. The RIVs results revealed that there was reduction in the densities of the herbaceous weeds flora at 45 DAT. However, there were increase in RIVs of *Tridax procumbens*, *Portulaca oleracea* and *Andropogo ngayanus*. *Acalypha fibriata* had the highest RIV of 22.11, followed by *Tridax procumbens* (RIV; 13.41), while the lowest RIV 2.71 was from *Ipomea erioarpa* (Table 2).

Table 2: Herbaceous composition and Relative Importance Value (RIV) of herbaceous of weeds flora on the experimental site

	DAY 0			15 DAYS AFTER TREATMENT			30 DAYS AFTER TREATMENT			45 DAYS AFTER TREATMENT		
S/N	Species	Family	RIV	Species	Family	RIV	Species	Family	RIV	Species	Family	RIV
1	*Acalypha fibriata*	Euphorbiaceae	22.41	*A. fibriata*	Euphorbiaceae	10.51	*A. fibriata*	Euphorbiaceae	17.51	*A. fibriata*	Euphorbiaceae	22.11
2	*Boerhavia diffusa*	Nyctaginaceae	18.90	*B. diffusa*	Nyctaginaceae	8.21	*B .diffusa*	Nyctaginaceae	10.31	*T. procumbens*	Tiliacea	13.41
3	*Andropogon gayanus*	Poaceae	13.81	*C. benghalensis*	Commelinaceae	5.99	*T. procumbens*	Tiliacea	9.48	*B. diffusa*	Nyctaginaceae	11.71
4	*Euphorbia heterophylla*	Euphorbiaceae	11.61	*C. lobatus*	Euphorbiaceae	5..35	*P. oleracea*	Portulacaceae	7.55	*P .oleracea*	Portulacaceae	10.34
5	*CommelinaBenghalensis*	Commelinaceae	9.34	*T. procumbens*	Tiliacea	4.52	*E. heterophylla*	Euphorbiaceae	7.05	*A. gayanus*	Poaceae	10.33
6	*Ipomoea erioarpa*	Convolvulaceae	8.91	*P .oleracea*	Portulacaceae	3.22	*C. benghalensis*	Commelinaceae	6.23	*C. lobatus*	Euphorbiaceae	8.51
7	*Tridax procumbens*	Tiliacea	6.13	*E. heterophylla*	Euphorbiaceae	3.05	*C. lobatus*	Euphorbiaceae	5.35	*E. heterophylla*	Euphorbiaceae	8.40
8	*Croton lobatus* L.	Euphorbiaceae	5..81	*A .gayanus*	Poaceae	2.62	*Phyllantus amarus*	Euphorbiaceae	5.23	*C. benghalensis*	Commelinaceae	7.53
9	*Trianthema portulaca*	Tiliacea	3.22	*T. portulaca* L.	Tiliacea	2.33	*A. gayanus* K.	Poaceae	4.91	*T. portulaca*	Tiliacea	5.92
10	*Portulaca oleracea*	Portulacaceae	0.48	*I. erioarpa* R.	Convolvulaceae	0.00	*T. portulaca* L.	Tiliacea	1.52	*P.amarus*	Euphorbiaceae	5.23
11							*P .oleracea* L.	Portulacaceae	1.52	*I. erioarpa*	Convolvulaceae	2.71

Community structure of weeds flora on the experimental study site

The values obtained from the results for the Taxa in each of the selected weed species enumerated on the experimental site ranged from 10 to 12. The Taxa was found to be highest at Day 0, 30 and 45 DAT, respectively and lowest at 15 DAT (Table 3). The Dominance indices ranged from 0.09 to 0.23. Dominance index result was found to be highest at 45 DAT and lowest at Day 0, (Table 3). Shannon-Wiener index values ranged from 2.22 to 2.39 and was found to be highest at Day 0 and lowest at 15 DAT. Results on the Evenness index ranged from 0.84 to 0.91 which was found to be highest at Day 0 and lowest at 15 DAT (Table 3).

Table 3: Species Diversity of Weed Flora at the Experimental Site

Diversity Indices	Day 0	Day 15	Day 30	Day 45
Taxa S	12	10	12	12
Dominance _ D	0.098	0.1157	0.137	0.231
Shannon _ H	2.398	2.223	2.230	2.319
Evenness E^H/S	0.916	0.842	0.849	0.903

Effects of C*ommelina benghalensis* extract and glyphosate herbicide on Okra (*Abelmoschus esculentus*) growth and yield parameters at Weeks After Sowing (WAS)

Results presented on Table 4 revealed significant differences ($p \leq 0.05$) from extract and glyphosate treatments on okra plant heights (PH) at 4, 6 and 8 WAS. The T3 at 4 WAS had the maximum value (14.87cm) of okra plant height with no significant differences ($p \leq 0.05$) from the other treatments (T1, T2, T4, T5, T6, T7 and T8). However, T6 recorded the lowest value (8.37 cm) of PH with significant difference ($p \leq 0.05$) from T3. Also at 6WAS, T3 recorded the highest PH (26.71cm) with no significant difference when compared with T2, T4 and T7 treatments. A significant difference ($p \leq 0.05$) was observed between T3 and T1, with the latter (T1) having the minimum value (16.53cm). Results obtained at 8WAS, showed that T3 had the highest (43.36cm) PH, while the lowest value 26.53cm was recorded from T6 (Table 4).

A significant difference ($p \leq 0.05$) was observed at 6WAS on the okra number of leaves (NOL) produced (Table 4). Treatments T3, T5 and T7 had the highest similar values of 7.33, respectively. Also T1 and T8 had similar values (6.66 and 6.33), respectively and were significantly different from other treatments. Result at 8WAS showed all other treatments having the same highest value (8.00) of NOL, while T1 had the lowest NOL (7.00) and significantly different from others (Table 4).

Results on stem diameter (SD) at 4 and 8 WAS showed significant difference ($p \leq 0.05$) among the treatments. Treatment T3 had the maximum value (2.57mm) of okra SD, while T6 recorded the minimum value (1.71mm) (Table 4) at 4WAS. Results obtained at 8WAS revealed T3 having the highest value (7.31mm) SD, while T8 recorded lowest value (4.04 mm) (Table 4).

Significant differences ($p \leq 0.05$) were observed among the treatments on okra yield (number of fruits (NOF)/ plant and weight of fruits per plant) as presented in Table 4. The T5 had the highest (12.67) NOF, while T2 recorded lowest (7.33) NOF. Results showed T7 having the highest (23.94g) fruit weight followed by T8, while T2 (control) recorded lowest (10.02g) fruit weight (Table 4).

Table 4: Effects of C*ommelina benghalensis* extract and glyphosate herbicide on Okra (*Abelmoschus esculentus*) growth and yield parameters at Weeks After Sowing (WAS)

Treatments	PLANT HEIGHT (cm)			NUMBER OF LEAVES			STEM DIAMETER (cm)			No of Fruits/plant	Weight of Fruits/plant (g) (Yield)
	4	6	8	4	6	8	4	6	8		
T1	10.37abc ±0.3	16.53d ±1.68	26.76d ±3.48	5.33a ±0.33	6.66ab ±0.33	7.00b ±0.00	1.82bc ±0.22	3.09a ±0.22	4.54cd ±0.42	8.00c ±0.66	12.85d ±0.91
T2	11.43abc ±0.4	22.46abc ±0.95	34.43bc ±3.54	5.33a ±0.33	7.00a ±0.33	8.00a ±0.00	2.31ab ±0.22ab	3.26a ±0.11	5.67bc ±0.55	7.33bc ±0.71	10.02e ±0.42
T3	14.87a ±1.8	26.71a ±0.41	43.36a ±1.30	5.33a ±0.33	7.33a ±0.33	8.00a ±0.00	2.57a ±0.11	3.18a ±0.11	7.31a ±0.10	8.00c ±0.62	10.22e ±1.01
T4	11.43abc ±1.5	21.73abcd ±2.28	29.46cd ±2.43	5.00a ±0.00	7.00a ±0.33	8.00a ±0.00	2.01abc ±0.11	3.01a ±0.33	5.56bcd ±0.71	9.67abc ±0.30	20.37b ±1.12
T5	12.43abc ±2.2	21.11bcd ±2.01	29.61cd ±2.29	5.67a± 0.33	7.33a ±0.33	8.00a ±0.00	1.97bc ±0.80	3.12a ±0.22	5.37bcd ±0.33	12.67a ±0.82	16.22cd ±0.71
T6	8.37c ±1.4	19.06cd ±0.60	26.53d ±1.28	5.33a ±0.33	5.66a ±0.33	8.00a ±0.00	1.71c ±0.11	2.13a ±0.00	4.24cd ±0.12	8.33c ±0.32	9.37e ±0.42
T7	13.13ab ±1.9	25.23ab ±1.43	38.90ab ±3.08	5.67a ±0.33	7.33a 0.33	8.00a ±0.00	2.02abc ±0.11	3.45a ±0.33	6.94a ±0.33	12.33ab ±1.52	23.94a ±2.41
T8	14.23abc ±0.	19.91bcd ±1.90	34.91bc ±2.21	5.00a ±0.00	6.33ab ±0.00	8.00a ±0.00	2.47abc ±0.40	2.89a ±0.11	4.05ab ±0.12	10.00abc ± 0.61	17.58bc ±1.52

T1= Recommended rate, T2= Control, T3= Leaf +Shoot 100%, T4= Leaf +Shoot 50%, T5= Leaf extracts 100%, T6= Leaf extract 50%, T7= Glyphosate (half of recommended rate), T8= Glyphosate (half of recommended rate) + 50% (Leaf +Shoot) extract.

Discussion

Phytochemical screening in this study revealed the presence of phenolics, saponins, alkaloids, flavonoids, steroids, tannins, glycosides, anthraquinone and terpenoids in the leaves and stem extract of *Commelina benghalensis.* This is in support of the findings by Ibrahim *et al.* (2010) who reported that the phytochemical screening carried out on *Commelina benghalensis* showed the presence of tannins, glycosides, flavonoids and saponins (secondary metabolites) (Rizvi *et al*., 1992; Vokou, 2007)). However, the presence of terpenoids, steroids, phenolics and anthraquinones revealed from this study were not detected from the report of Ibrahim *et al.* (2010). This may be due to the age of the plant, location and environmental conditions. Presence of some of these secondary metabolites suggests that the plant might be of herbicidal importance and supports the basis for its use. Also the presence of flavonoids suggests that the plant might have an allelopatic activity (Rizvi *et al*., 1992; Vokou, 2007). Tannins and Flavonoids are phenolic compounds (secondary metabolites) that were present in the extract which might be accountable for the toxic herbicidal ability of *C. benghalensis.* Some secondary metabolite compounds from plant chemicals with allelopatic activities had been reported to reduce weed infestation with inhibitory/toxic and stimulatory effects due to their herbicidal activities (Vokou, 2007).

Plant height of okra in this study was significantly improved by all the treatments with tallest plants height recorded from plots treated with 100% leaf + shoot extract. Also the extract treatments significantly influenced the number of leaves and stem diameter. Increase in okra growth parameters might be possibly due to suppression of weeds in treated plots as a result of the toxic effects of the extracts. Similar findings were reported by Mvumi *et al*. (2012) that application of moringa leaf extract increased growth of tomato.

Okra yield was significantly enhanced by suppressing weeds through pre emergence herbicides alone and in combination with allelopathic *C. benghalensis* water extracts. The yield of okra in other treatments (either at their recommended rates or with allelopathic extract) were higher than the weedy check control statistically. The reason for increase in the yield of okra over control may be due to the suppression of weeds and probably the allelopathic toxic effects of *C. benghalensis* extract which promoted the okra growth and ultimately increased the yield (Jabran *et al.,* 2012). Increase in okra yield may also be as a result of inhibition of weeds by allelopathic toxic *C. benghalensis* extract which facilitated less competition and better nutrients availability for the okra plants. This result supports the findings of Awogbade *et al*. (2018) that the *C. bengalensis* powder as a bio-herbicide significantly increased the plant height, stem girth and yield of *Solanum macrocapon* (eggplant).

All the weed treatment combinations (glyphosate and *Commelina benghalensis* extract) significantly reduced the weed density on the experimental site compared to the control. However, the maximum reduction in weed density was observed in glyphosate half recommended rate plus extract (2.66mls in 500 ml of water + 50% leaf and shoot extract), which may be due to synergistic effects of allelochemicals with synthetic herbicide. This study revealed that 50% whole plant (leaf +shoot) of *Commelina benghalensis* aqueous extract plus half recommended dose (2.66mls in 500mls of water) of pre-emergence systemic herbicide (glyphosate) suppressed the growth of weeds of okra at 15, 30 and 45 Days After Treatment (DAT) that is, throughout the critical weed interference period of okra plants.

The population of *Acalypha fibriata* and *Ipomea eriocarpa* found at the study area was greatly reduced at glyphosate half recommended rate plus extract (2.66mls in 500 ml of water + 50% leaf + shoot extract) when compared with other treatments. The results conformed with the report of Cheema *et al.* (2002) that, herbicide dose can be reduced in combination with allelopathic plant water extracts as phytotoxin. The same authors, Cheema *et al.* (2003) also reported that sorghum water extract could be used with reduced dose of synthetic herbicide for effective weed control in cotton.

High Shannon-Weiner indices recorded at Day 0 and 45 Days after treatments (DAT) indicated high diversity, while the relatively low Shannon Wiener indices at 15 and 30 DAT implied low diversity; and that no species was dominant at the experimental site. Also, the equitability/ evenness indices that tended towards one in day 0 and 45 DAT indicated random distribution of species, while the low Dominance index in day 0 confirmed the random distribution of all species present at the study area. However, the relatively high Dominance indices (0.137) and (0.231) at 30 and 45 DAT, respectively can be accounted for by the emergence of new weeds (*Ipomea eriocarpa* and *Phyllanthus amarus*) and also the increase in Relative importance value (RIV) of weeds present at the study area.

Conclusion

Studies of this nature with different combination of extracts and herbicides (glyphosate half recommended rate plus extract: 2.66mls in 500 ml of water + 50% leaf + shoot extract) may be continued for developing a sound weed control strategy for okra, having more reliance on bio-herbicides than synthetic herbicides. Reduced synthetic herbicide doses in combination with plant water extracts would minimize cost of production, over use of synthetic herbicides and environmental pollution as view points to environmental toxicologists. Hence there will be increase in farmers' income, food quality and safety. Farooq *et al.* (2011) had stressed the need for development of new plant combinations with a reduced dose of herbicides for weed control at a specific crop level in order to minimize costs of weed management. The inhibitory/toxic and stimulatory effects of the herbicide treatments were higher between Day 15 and Day 30 DAT, while at Day 45, the herbicide has reduced its potency (toxicity). Therefore, the effectiveness of this bio-herbicide

(*Commelina benghalensis*) should be considered for usage between Day 15 and Day 30 of treatment application for optimum yield and maximum production of okra in organic agriculture for food sustainability.

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Conservation Status and Growth Response of *Cnidoscolus Aconitifolius* (Mill.) Johnst. to Fertilizer in Ibadan, South-western Nigeria

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Abstract

Cnidoscolus aconitifolius (Mill.) Johnst., is a domesticated leafy vegetable. *Knowledge of* its ethnobotanical use, growth biology under soil amendments, and acceptability is insufficient in southwest Nigeria. The study evaluated its response to soil amendments and conservation potential in metropolitan and agrarian local government areas (LGAs) of Ibadan, Nigeria. The study was conducted in the Crop Garden of the Department of Crop Protection and Environmental Biology, University of Ibadan (N^{0}7.451655, E^{0}03.89708), and in six agrarian and five metropolitan LGAs. The growth experiment consisted of four treatments: A no-amendment control, cattle dung, poultry manure, and NPK15:15:15 replicated thrice and laid out in a completely randomized design. Data were collected on plant height, the number of leaves, stem diameter, total leaf area, and number of branches. They were analysed using analysis of variance (ANOVA) with significant means separated by Fisher's LSD (p=0.05). A structured questionnaire was administered using the snowballing procedure. Data were descriptively and inferentially analysed. No significant difference was observed between plant heights of no-amendment control and other treatments. NPK 15:15:15 treatments had the lowest mean number of leaves. Stem cuttings planted in amended soils had lower diameters (1.5 cm, 1.7 cm, 1.3 cm for no-amendment control, poultry manure, and cattle dung respectively) in 10 weeks after sowing compared to the control (2.0 cm). Similar trend was observed for total leaf area. Amendments with poultry manure gave the highest mean number of branches at 10 weeks after sowing, followed by NPK 15:15:15 while cattle dung had the lowest mean number of branches. A correlation coefficient (1.00) indicated perfect positive relationship between ages of respondents and viewed that its cultivation would mitigate climate change impact in Ibadan. Farmers would consider cultivating it. The potential conservation preference ($\alpha_{(0.05)}$=0.295) of the crop among younger respondents could confer protection on it. The study revealed that *Cnidoscolus aconitifolius* can develop to its full potential with little or no soil amendments, probably being a deep-rooting plant. The awareness among residents in Ibadan could ensure its conservation. In addition, the cultivation should be encouraged as a low-input vegetable to ameliorate food insecurity.

Statut de conservation et réponse de croissance de *Cnidoscolus Aconitifolius* (Mill.) Johnst. aux engrais à Ibadan, au sud-ouest du Nigeria

Résumé

Cnidoscolus aconitifolius (Mill.) Johnst., est un légume feuillu domestique. La connaissance de son utilisation ethnobotanique, de la biologie de la croissance sous amendement du sol et de son acceptabilité est insuffisante dans le sud-ouest du

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Nigeria. L'étude a évalué sa réponse aux amendements du sol et au potentiel de conservation dans les zones métropolitaines et agraires des communes (LGAs) d'Ibadan, au Nigeria. L'étude a été menée dans le Crop Garden du Département de protection des cultures et de biologie environnementale de l'Université d'Ibadan (N07.451655, E003.89708) et dans six communes agraires et cinq villes métropolitaines. L'expérience de croissance consistait en quatre traitements : un contrôle sans modification, de la bouse de bétail, du fumier de volaille et du NPK15:15:15 répétés trois fois et disposés selon un schéma complètement aléatoire. Des données ont été recueillies sur la hauteur de la plante, le nombre de feuilles, le diamètre de la tige, la surface foliaire totale et le nombre de branches. Ils ont été analysés à l'aide d'une analyse de variance (ANOVA) avec des moyennes significatives séparées par le LSD de Fisher (p = 0,05). Un questionnaire structuré a été administré en utilisant la procédure de boule de neige. Les données ont été analysées de manière descriptive et inférentielle. Aucune différence significative n'a été observée entre la hauteur des plantes du témoin sans amendement et celle des autres traitements. Les traitements NPK 15:15:15 avaient le nombre moyen de feuilles le plus bas. Les boutures de tiges plantées dans des sols amendés avaient des diamètres inférieurs (1,5 cm, 1,7 cm, 1,3 cm pour le témoin sans amendement, le fumier de volaille et le fumier de bovin respectivement) 10 semaines après le semis par rapport au témoin (2,0 cm). Une tendance similaire a été observée pour la surface foliaire totale. Les amendements avec du fumier de volaille ont donné le nombre moyen de branches le plus élevé à 10 semaines après le semis, suivis de NPK 15:15:15 tandis que la bouse de bétail avait le nombre moyen de branches le plus faible. Un coefficient de corrélation (1,00) indiquait une relation positive parfaite entre les âges des répondants et considérait que sa culture atténuerait l'impact du changement climatique à Ibadan. Les agriculteurs envisageraient de le cultiver. La préférence potentielle pour la conservation (α (0,05) =0,295) de la culture chez les répondants plus jeunes pourrait lui conférer une protection. L'étude a révélé que *Cnidoscolus aconitifolius* peut se développer à son plein potentiel avec peu ou pas d'amendements du sol, étant probablement une plante à enracinement profond. La sensibilisation des habitants d'Ibadan pourrait assurer sa conservation. En outre, la culture devrait être encouragée en tant que légume à faible apport pour palier l'insécurité alimentaire.

Mots-clés:
Cnidoscolus aconitifolius,
Légume indigène,
Enquête ethnobotanique,
Sécurité alimentaire,
Agriculture à faibles intrants.

Introduction

Indigenous African vegetables, though threatened and underutilized, are crucial in the sustainability of local economies, human nutrition, and community livelihoods (Rubaihayo, 2002; Uusiku *et al.,* 2010; Wemali, 2014). They are defined as indigenous or exotic species which due to long use have become part of the culture of a community (Dube *et al.,* 2017). Plant Resources of Tropical Africa (PROTA) estimated 397 useful indigenous African vegetables out of 6,376 useful African plants (Jansen, 2004). In addition, Town and Shakleton (2019) reported that around 1000 different species of indigenous and naturalized vegetables contribute to the dietary diversity, food security, and livelihoods of populations across sub-Saharan Africa. While few are cultivated, many indigenous vegetables in Africa are in the wild (Aworh, 2018). Indigenous communities harvest them mainly from the wild and thus are not commonly encountered in urban African markets.

One of such rarely cultivated indigenous African leafy vegetables is *Cnidoscolus aconitifolius* (Mill.) Johnst. It belongs to the family *Euphorbiaceae* and originated from the Maya region of Guatemala, Belize in southeast Mexico (Ross-Ibarra and Molina-Cruz, 2002). In 1977, *C. aconitifolius* was introduced to Ghana from an agricultural research station in Puerto Rico (Newton, 1984). *In the tropics, Cnidoscolus aconitifolius is a perennial shrub,* generally called spinach tree or chaya. It is consumed as a vegetable in soups in southwest, Nigeria where it is called "Efo Iyana Ipaja" In southeast, Nigeria, it is called "Hospital too far" because of its medicinal benefits (Iwalewa *et al*., 2005). It has been demonstrated to contain phenols, saponins, and cardiac glycosides (Jiménez-Aguilar and Grusak, 2015). High fibre content and antibacterial activities of this plant have also been reported (Awoyinka *et al.,* 2007), as well as its high proximate content (Adanlawo and Elekofehinti, 2012). Like many wild vegetables, it is not usually infested by insects, and it is drought tolerant. Thus, it is a valuable vegetable in areas with low precipitation and consequently a shortage of green vegetables.

Although *Cnidoscolus aconitifolius*has has so many uses, including ameliorative function against certain toxic substances (Azeez *et al.*, 2010) and other phytomedicinal benefits (Iwuji *et al.,* 2013), it is not widely cultivated because its leaves possess stinging hairs along the petiole and bottom margin of the lamina (Ross-Ibarra and Molina-Cruz, 2002). Its milky exudate may also cause itching, making handling quite difficult. These may have contributed to its relatively low potential as a leafy vegetable compared to other commonly utilized vegetables like *Amaranthus cruentus* and *Corchorus olitorius* in southwest Nigeria. The conservation status of *Cnidoscolus aconitifolius* is yet to be assessed according to the IUCN Red List of Threatened Plants Status (2001). Although it has been established that *C. aconitifolius* has potential uses as a leafy vegetable with potential health benefits (Kutiand Torres, 1996), there is insufficient information on its growth biology and general acceptability since it is not a widely cultivated plant in southwest Nigeria.

Its conservation and utilization may be beneficial if it could be cultivated cheaply. Soil amendments in production of vegetables is beneficial (Akanbi and Togun, 2002). Use of animal wastes as fertilizers, poultry manure, and cow dung are recognised as perhaps the most desirable of natural amendments because of their high nitrogen content (Sloan *et al*., 2003). However, there is a dearth of specific information on use of soil amendments in the cultivation of *Cnidoscolus aconitifolius.* Therefore, the objectives of this study were to evaluate the conservation status of *Cnidoscolus aconitifolius* in metropolitan and agrarian local government areas in Ibadan, southwest Nigeria, and to determine the early growth response of *C. aconitifolius* stem cuttings to organic and inorganic soil amendments.

Materials and Methods

Study site

The study was conducted in Ibadan (latitude 7.226536N and longitude 3.543546E), southwest Nigeria. The city shares two main vegetation zones: rain forest in the southern portion and derived savanna in the northern fringes of the city. The city exhibits a bimodal pattern of rainfall with a total of 1253 mm of rainfall distributed over nine months (*NIMET, 2017)*, with two relatively short dry seasons punctuated by the rainy seasons.

The study consisted of a field and a pot experiment. This field study was carried out in six agrarian and five metropolitan local governments (Figure 1) in Ibadan to evaluate the conservation status of *Cnidoscolus aconitifolius*. The agrarian local governments sampled in Ibadan were Lagelu, Akinyele, Oluyole, Egbeda, Ido, and Ona-Ara while the metropolitan local governments were Ibadan North, Ibadan Southwest, Ibadan Southeast, Ibadan Northwest, and Ibadan Northeast.

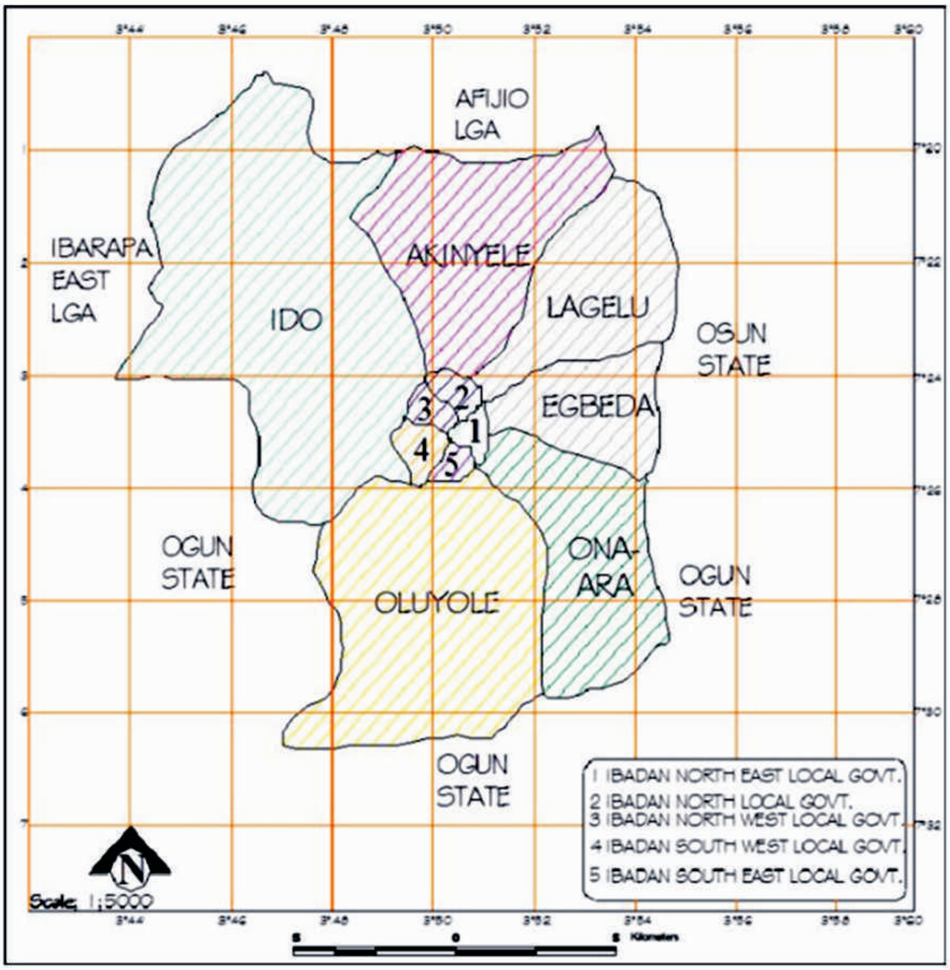

Figure 1: Map of the agrarian (named) and metropolitan (numbered 1-5¬) Local Government Areas of Ibadan
Source: Ministry of Lands and Housing, Ibadan

Data collection

Data were collected from users of the vegetable using a non-probabilistic snowballing procedure where respondents were selected based on referrals. The selection criteria of respondents were based on their ability to identify *C. aconitifolius* on a clear coloured photo provided (Plate 1) and its occurrence in their place of residence (metropolitan LGAs) and farms/compounds (agrarian LGAs). Referrals were also based on the criteria.

Demographic and socio-economic characteristics of respondents, knowledge of *Cnidoscolus aconitifolius*, general perception of the vegetable, and perception on its conservation status were assessed. Perception of respondents about the plant was assessed using a Likert scale.

Pot experiment

The pot experiment was conducted to determine the effect of soil amendments on the growth features of *Cnidoscolus aconitifolius*in the Crop Garden of the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan. The crop garden is located on latitude 7.451655°N and longitude 3.89708°E, 198 m ASL.

Topsoil (0-15 cm depth) was collected from the crop garden of the Department to fill experimental pots and for routine soil analyses. The soil for the analyses was collected from the topsoil using a soil auger in three replicates. Soil analysis was conducted at De Image Laboratory Services, Ibadan, Nigeria. Poultry manure and cattle dungs were collected from the Teaching and Research Farm, University of Ibadan, Ibadan on latitude 7.272221°N and longitude 3.533365°E at 184 m ASL. The manures were cured for three weeks at the farm and analysed at the Department of Agronomy, University of Ibadan, Ibadan.

Stem cuttings of *Cnidoscolus aconitifolius* were collected from Agricola Herbal Garden, Barika, Ibadan, from a three-year- old plant by using secateurs to obtain stems that possessed six nodes.

Experimental design

The experiment was made up of four treatments (No amendment control, cattle dung, poultry manure, and NPK15:15:15 applications). It was laid out in a completely randomized design, with each treatment replicated three times. Twelve experimental pots were filled with 4 kg of soil each. One Stem cutting of *Cnidoscolus aconitifolius* was planted in each pot with three nodes in the soil and three nodes above the soil. Exactly 50 g of NPK 15:15:15 per plant was applied to the pots according to the treatments and following the recommended amount of NPK 15:15:15 in the cultivation of *Jatropha curcas* according to Ojiako *et al*. (2011). Equivalent weight of 20 t/ha of cattle dung and poultry manure was also applied to the appropriate pots following the recommended amount of cattle dung and poultry manure according to Adeniji *et al.* (2019). The remaining pots with no soil amendments served as control. The plants were watered to field capacity as needed.

The amount of fertilizer used per pot was calculated using the formula of Udo and Ogunwale (1986).

$$x = \frac{\text{Soil weight pot (kg)}}{2 \times 10^6 \text{ kg soil}} \text{X} \frac{\text{Recommended Rate}}{\text{Concentration of Nitrogen}} X100$$

Data collection

Data collection on plant height, number of leaves, stem diameter, total leaf area, and number of branches commenced two weeks after planting (WAP). Data were collected using a meter rule for measurement of plant height, a vernier caliper for measurement of stem diameter while the number of leaves were counted. Leaf area was calculated using a regression equation generated on Microsoft Excel: Y=15.172x - 65.52 for the crop under study following the graphical method described by Tayo and Togun (1984).

Data analyses

Data from the questionnaire were analysed for descriptive and inferential statistics using IBM SPSS Statistics Version 23. The models used included partial correlation and constabulation. Growth data were analysed using ANOVA. Means were separated by Fisher's LSD at a 5% level of significance. Alpha values less than 0.05 were considered significant, $p<0.05$.

Results

The respondents lived in their own houses (40%), rented (50%), leased (5%), or other types of residences, such as family house (5%) (Figure 2). It was observed that 15% of the respondents have lived in their place of residence for one to fifteen years (Figure 3), while a small proportion of respondents lived between six months and six years in owned residences.

Information on conservation and ethno-botany of Cnidoscolus aconitifolius (Mill.) Johnst., in Ibadan

The largest number of respondents (25%) preferred the conservation and ethno-botanical use of *C. aconitifolius* in Ibadan North local government area (LGA), where it was mostly used as a live fence. Its conservation was preferred by only 5% of respondents in Ido LGA (Figure 4).

Perception of respondents on the importance of Cnidoscolus aconitifolius (Mill.) Johnst., based on age and length of stay in residence

A perfect correlation value of 1.00 was recorded between age and the response of the respondents to whether *C. aconitifolius* can alleviate poverty, mitigate climate change, and whether it is considered a vegetable for the poor that is not easily perishable (Table 1). A correlation coefficient value of 0.705 was recorded between the view on the ability to mitigate climate change and whether it was considered a vegetable for the poor and length of stay in residence. This indicates that there is a strong positive relationship between their views and the length of stay. The $P_{(0.05)}$ value of 0.295 indicated a significant relationship between the two variables (Table 2). Many older people reported that it survived very well in the dry season (r=0.705) as well as its ability to cause skin irritation (Table 2).

Perception of respondents on the conservation status of *Cnidoscolus aconitifolius* (Mill.) Johnst., based on age and length of stay in residence

Older respondents would not consider cultivating it while younger respondents would consider cultivating it. Respondents that had stayed longer in their place of residence significantly ($\alpha_{(0.05)}$ = 0.398) preferred other vegetables to it (Table 2).

Furthermore, a perfect correlation value of 1.00 was recorded between the length of stay and the response of the respondents to whether *C. aconitifolius* survives well in the dry season and whether it causes skin irritation. This indicates that people who had stayed longer in their place of residence significantly ($\alpha_{(0.05)}$ = 0.295) believed that it survives well in the dry season and that it causes skin irritation (Table 2).

Soil and Manure Characteristics

The soil analysis used for the cultivation of *Cnidoscolus aconitifolius* had a pH of 7.8, slightly alkaline (ph=7.8), with total nitrogen of 3.6 mg/kg, available phosphorus of 153.78 mg/kg, and organic carbon concentration of 32.4 mg/kg. The soil according to the USDA Soil Classification, is loamy sand in texture (Table 3). The poultry manure contained a total nitrogen value of 38.67 mg/kg which was higher than its value in cattle dung (1.96 mg/kg). Poultry manure also contained a higher amount of organic carbon (37.459), compared to cattle dung (19.715). The same trend was observed for the amount of available phosphorus (Table 3).

Effects of soil amendments on growth parameters of *Cnidoscolus aconitifolius* (Mill.) Johnst.

Effect of soil amendments on height

Soils amended with cattle dung and poultry manure had taller plants compared to the no-amended soil across the weeks (Figure 5). The maximum mean height attained by *Cnidoscolus aconitifolius* at 2 WAP was 19.3 cm under cattle dung treatment, while it was 14.2 cm and 14.1 cm with poultry manure and NPK applications, respectively. At 10 WAP, the maximum mean heights attained were 32.4 cm, 29.3 cm, and 26.8 cm for cattle dung, poultry manure, and NPK 15:15:15 respectively, while the control at 10 WAP was 28.7 cm. It was also observed that cattle dung exhibited the highest effect on the height of *C. aconitifolius,* followed by poultry manure, with NPK 15:15:15 having the lowest effect across the weeks, from 2 WAP to 10 WAP (Figure 5). However, there was significant difference between the effects of cattle dung and other treatments (which are statistically similar) on the height of *C. aconitifolius* across the weeks.

Effect of soil amendments on the number of leaves

It was observed (Figure 6) that at 2 WAP, 4 WAP, and 6 WAP, the no-amendment control had the highest mean number of leaves (5.33, 9.67, and 11.33), Poultry manure application gave the highest mean number of leaves at 8 WAP (16.67) while plants that received cattle dung had the highest mean number of leaves at 10 WAP (20). It was also observed that NPK 15:15:15 had the lowest mean number of leaves across the weeks, from 2 WAP to 10 WAP. However, there was no significant mean difference between the number of leaves of control and that of other treatments across the weeks (Figure 6).

Effect of soil amendments on stem diameter

It was observed that *C. aconitifolius* stems planted in soil amended with poultry manure, cattle dung and NPK 15:15:15 had a lower diameter across the weeks, compared to the control with no soil amendment (Figure 8). At 2 WAP, the mean stem diameter of control (1.5 cm) had a highly significant mean difference from that of *C. aconitifolius* planted in soil amended with NPK 15:15:15 (0.9 cm) and from that of soil amended with cattle dung (1.1 cm). The control was also significantly different from poultry manure. At 4 WAP, the stem diameter of control had a highly significant mean difference from that of *C. aconitifolius* planted in soil amended with cattle dung and NPK15:15:15. However, there was no significant difference between cattle dung and NPK 15:15:15. At 6 WAP, there was a highly significant mean difference between control and *C. aconitifolius* planted in soil amended with NPK 15:15:15. The same trend was observed at 8 WAP and 10 WAP (Figure 7). Also at 10WAP, a significant mean difference was observed between the stem diameter of control and other treatments.

Effect of soil amendments on total leaf area

C. aconitifolius planted in soil amended with NPK 15:15:15, poultry manure, and cattle dung had lower total leaf area compared to the control having no soil amendment (Figure 8). *C. aconitifolius* planted as control had the highest total leaf area, followed by those planted in soil amended with cattle dung while NPK 15:15:15 had the lowest across the weeks. It was observed that at 2WAP, there was a high significant mean difference between the total leaf area of control (24.551 cm^2) and *C. aconitifolius* planted in soil amended with poultry manure (10.698 cm^2) and NPK 15:15:15 (5.009 cm^2) while there was a significant mean difference between control and *C. aconitifolius* planted in soil amended with cattle dung (15.124 cm^2). At 6 WAP, no significant mean difference in total leaf area was observed in all the treatments, but at 8 WAP, there was a significant mean difference between control (442.154 cm^2) and NPK 15:15:15 (215.782 cm^2). At 10 WAP, the total leaf area of *C. aconitifolius* planted without soil amendment (Control) again differed highly significantly from that of NPK 15:15:15 (Figure 8).

Effect of soil amendments on number of branches

It was observed that at 2 WAP, the number of branches for all treatments did not significantly vary but at 4 WAP, all other treatments had a lower number of branches compared to the control with no soil amendments (Figure 9). At 10 WAP, it was observed that *C. aconitifolius* planted in soil amended with poultry manure had the highest mean number of branches (3), followed by those planted in soil amended with NPK 15:15:15 (2.67) and those planted in soil amended with cattle dung having the lowest mean number of branches (2.33).

Figure 2: Percentage of respondents in the different residence types where *C. aconitifolius* is cultivated in Ibadan in 2019

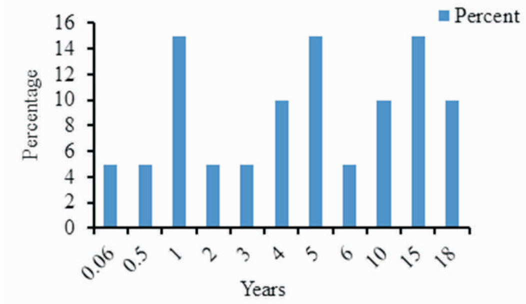

Figure 3: Percentage of respondents length of stay in residences where *Cnidoscolus aconitifolius* (Mill.) Johnst. is cultivated in Ibadan in 2019

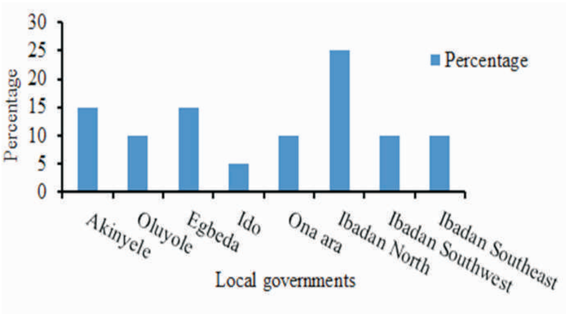

Figure 4: Percentage of respondents favouring the conservation and ethno-botanical use of *C. aconitifolius* in the sampled local governments in Ibadan in 2019

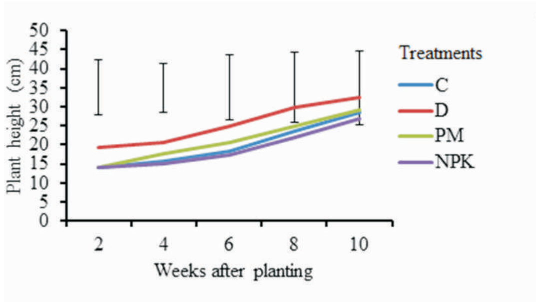

Figure 5: Effect of soil amendments on the height of *Cnidoscolus aconitifolius* (Mill.) Johnst. in Ibadan in 2019

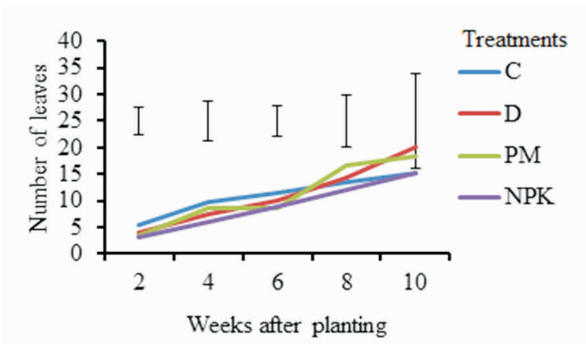

Figure 6: Effect of soil amendments on the number of leaves of *Cnidoscolus aconitifolius* (Mill.) Johnst. in Ibadan in 2019

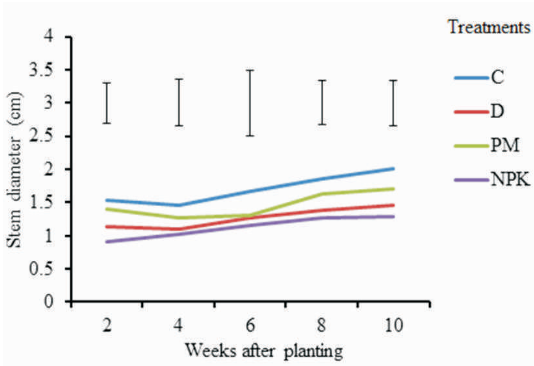

Figure 7: Effect of soil amendments on Stem Diameter of *Cnidoscolus aconitifolius* (Mill.) Johnst. in Ibadan in 2019

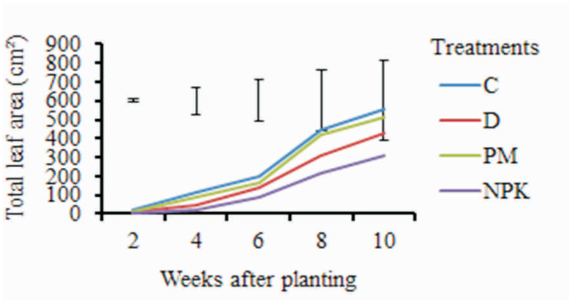

Figure 8: Effect of soil amendments on the total leaf area of *Cnidoscolus aconitifolius* (Mill.) Johnst., in Ibadan in 2019. Bars = $FLSD_{0.05}$

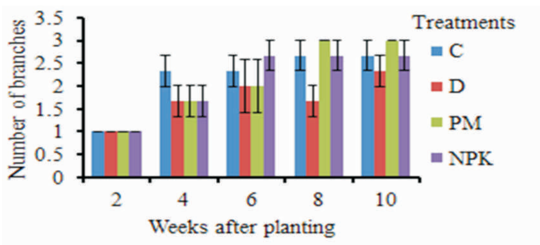

Figure 9: Effect of soil amendments on the number of branches of *Cnidoscolus aconitifolius* (Mill.) Johnst. in Ibadan in 2019. Bars = SE

Table 1: Perception of respondents on the importance of *Cnidoscolus aconitifolius* (Mill.) Johnst., based on age and length of stay in residence

Control Variables	Independent Variables	Statistics	Age	Length of stay
It can alleviate poverty	age	Correlation	1.000	.705
It can mitigate climate change		Significance (2-tailed)		.295
It is considered a vegetable for the poor It is not easily perishable		Df	0	2
It survives well in the dry season	Length of stay	Correlation	.705	1.000
It causes skin irritation		Significance (2-tailed)	.295	
It is a good edge plant		Df	2	0
Its acceptability is low				

Table 2: Perception of respondents on the conservation status of *Cnidoscolus aconitifolius* (Mill.) Johnst., based on age and length of residence in the locality

Control variables	Independent variable	Statistics	Age	Length of stay
Is its population reducing	Age	Correlation	1.000	.235
Would you consider cultivating it		Significance		.398
		Df	0	13
Is it difficult to multiply	Length of stay	Correlation	.235	1.000
Do you prefer other vegetables to it		Significance	.398	
		Df	13	0

Table 3: Physical and chemical properties of the soil, poultry manure, and cattle dung used for the experiment

Soil Parameters	Soil	Poultry Manure	Cattle Dung
pH in KCl	NA	9.10	6.6
pH in $H_2 0$	7.87	9.80	7.3
Organic Carbon (mg/kg)	32.4	37.459	19.71
		5	
Total Nitrogen (mg/kg)	3.6	3.867	0.196
Available Phosphorus (mg/kg)	153.78	0.674	0.168
Exchangeable Acidity (cmol/kg)	0.30	NA	NA
Sand (mg/kg)	832	NA	NA
Silt (mg/kg)	114	NA	NA
Clay (mg/kg)	54	NA	NA
Ca (cmol/kg)	14.04	0.1883	0.383
		8	
Mg (cmol/kg)	2.39	0.0040	0.005
		6	
K (cmol/kg)	0.85	0.513	0.625
Na (cmol/kg)	0.35	1100.00	2100.
		0	
Mn (mg/kg)	27.0	935.00	960.0
Fe (mg/kg)	25.2	1150.0	950.0
Cu (mg/kg)	0.674	10.60	7.40
Zn (mg/kg)	3.10	9.15	6.35
Textural Class	Loamy sand	NA	NA

Footnote: NA = Not Available

Discussion

The ethnobotanical use of *C. aconitifolius* was found to be popular among respondents in Ibadan as all the respondents confirmed the use of *C. aconitifolius* in food, medicine, house, and garden fencing. This indicates that people in Ibadan, especially those who have the plant cultivated in their residences have a good ethnobotanical relationship with *C. aconitifolius* which might confer some conservation protection on the crop.

They reported that it was less popular than vegetables like Jute mallow and others as a result of it being mostly regarded as a weed in some cropping systems. It was however not popular among the younger age group in the population, which is a critical player in vegetables (Juma *et al.*, 2015). A sizeable proportion of respondents who reside in the metropolitan part of Ibadan believed the vegetable could alleviate poverty connoting that there is hope for its cultivation in the city. Likewise, that it was recognized as a potential crop to mitigate climate change indicates more attention could be focused on its development to exclude what farmers considered as negative characteristics such as slow initial growth and itchiness. Younger respondents are in favour of its conservation with an indication that future generation of people in Ibadan, in spite of the constraints, would consider cultivating the plant.

Cow dung and poultry manure influenced the height of *Cnidoscolus aconitifolius* over 10 weeks. It supports the opinion of Akanbi and Togun (2002) that amaranth vegetables can benefit from the application of soil amendments. However, the stem cuttings grown in soils amended with NPK 15:15:15 showed minimal response compared to the control. This study has established that cattle dung significantly influenced the height of *C. aconitifolius*. The study further revealed that other growth parameters of *Cnidoscolus aconitifolius* can develop to its full potential in a loamy sand topsoil with the use of little or no soil amendments in the prevailing warm humid climate of Ibadan. The plant can thus be used as a low-cost feed for livestock due to its high protein content as considered by several researchers (Donkoh *et al*., 1999; Newton, 1984).

Conclusion and Recommendations

The knowledge of *Cnidoscolus aconitifolius* among the resident population in the metropolitan and agrarian local governments of Ibadan is encouraging for its continued existence. There is a positive awareness of its use, which is diverse. The various uses to which the crop could be put seem to be the driver of its existence and preference among the respondents. The older generations were of the view that it could help solve various environmental challenges, the most important of which are climate change, global warming, and greenhouse gas emissions. In view of this, the crop would gain general acceptance with the people for use as a crop to combat hunger and mitigate the environmental challenges of an urbanizing city. Interestingly, the benefit derivable from the cultivation of *Cnidoscolus aconitifolius* in Ibadan was more acknowledged with the increase in the number of years of existence. The perennial nature of the crop would confer more importance on it with the passing years among the residents of Ibadan city. Therefore, since there is hope for its continual existence, the use of extension workers is recommended to educate the populace on its cultivation potential either in the home garden or on a large scale.

It is also encouraged to be cultivated as a low-input vegetable that can ameliorate food insecurity. As an evergreen vegetable, its role in climate change mitigation cannot be over-emphasized, therefore, strict government policies should be put in place to encourage its cultivation. In addition, older people are advised to engage in volunteering activities by plantings to not only control climate change but to contribute to food security for the future generation.

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Appendix

Amount of NPK 15:15:15, Cattle dung and poultry manure applied per pot (x)

$$x = \frac{4\ \text{kg}}{2 \times 10^6\ \text{kg soil}} \text{X} \frac{66.65\ \text{kg}}{33.3}\ X100 \times 1000$$

= 0.45 g/pot of NPK 15:15:15

$$x = \frac{4\ \text{kg}}{2 \times 10^6\ \text{kg soil}} \text{X} \frac{15\ \text{kg}}{0.196}\ X100 \times 1000$$

= 15.3 g/pot of cattle dung

$$x = \frac{4\ \text{kg}}{2 \times 10^6\ \text{kg soil}} \text{X} \frac{15\ \text{kg}}{3.867}\ X100 \times 1000$$

= 0.78 g/pot of poultry manure (Udo and Ogunwale, 1986)

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Gaps/ Challenges of Ecological Agriculture and Organic Agriculture in West Africa

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Introduction

Agriculture remains the key sector for the economic development for most West African countries. Organic farming has a long history but show a recent and rapid rise. It has proven to have a sustainable way of ensuring food security therefore it is important to have baseline information on OA/EA in West Africa. The survey was carried out by the use of e-questionnaire to collect data from 201 organic practitioners across West African countries. This was done to gather information on stakeholders or organic and ecological agriculture in West Africa.

Results and Discussions

A total of two hundred and one (201) stakeholders were sampled from nine countries including Benin, Burkina Faso, Gambia, Ghana, Mali, Nigeria, Senegal, Sierra Leone and Togo. A total of nine organic agriculture stakeholder categories of operations were considered to analyse the gaps stakeholders in organic agriculture are facing. These included; advocacy, commodity/value chain, finance, policy, production, quality guarantee, research, trade/commerce and training formation.

Gaps/ Challenges of EA/OA in West Africa

1. Limited equipment and facilities for organic research
2. Lack of awareness, understanding, knowledge on organic agriculture
3. Unfavorable perception of stakeholders to organic agriculture practices
4. Lack of sponsors/access to finance for organic agriculture
5. Insufficient training of organic agriculture stakeholders
6. Poor network of stakeholders
7. Low availability of land area for Organic production
8. Poor transportation of organic materials
9. Environmental degradation(flood, bush burning, deforestation, climate change)

10. Insufficient, expensive labour/manpower
11. Improper documentation of agro-ecological production techniques
12. Insufficient organic markets for both inputs and output
13. Insufficient/expensive approved organic inputs (pesticides and fertilizers)
14. Limited pest & weed control measures
15. Unfavorable Govt. policies
16. Buffer zone
17. Certification and Quality Control procedures.
18. Low Govt. supportHigh/difficult livestock organic agriculture standard
19. Lack of organic product(s) pricing policy
20. Post-harvest loss and inadequate agro-processing of organic agriculture products
21. In adherence to organic agriculture principles & standard(s)

Probable Solutions for EA/OA gaps in West Africa

1. Adequate funding for organic research
2. Proper diffusion of ecological and organic practices and innovations for agriculture sustainability at large scale
3. Regular awareness on organic agriculture benefits and principles
4. Advocacy on need for funding organic agriculture activities
5. Training on innovative good practices already implemented by some farmers, their capitalization and knowledge on the production of exotic seeds
6. Promote exchanges and consultation between civil society actors for a contribution to the promotion of sustainable food and nutritional security,
7. Forging alliances and coalitions with other networks in the West African subregion,
8. There is a need to reconnect farmers to the land by linking their productive activities with nature conservation.
9. Creation of awareness on the need for stakeholders to invest on transportation of organic materials.
10. Nature conservation, here protecting biodiversity at genes, species and ecosystem levels,
11. Restore biodiversity of the environment.
12. Low technology and mechanization of production
13. Improved documentation of ecological agriculture practices through market outlets and appropriate policies.
14. Expanding marketing channels to enable everyone to access healthy products,
15. Proper labeling & identification of organic products,
16. Create a market for effective consumption of organic products
17. Establishment of a national distribution network for organic products
18. Provide quantity and quality of organic inputs to producers engaged in organic farming,
19. Acquisition of inputs Improve the productivity of agricultural production systems,
20. Improve the production of bio pesticides
21. More training on Organic Agriculture weed control measures
22. Have a regulatory law for organic farming sector to promote a pesticide-free diet in West Africa
23. Stakeholders should be trained on importance of this and encourage group farming among small scale producers to minimize loss of land for production due to buffer zone.

    National organic agriculture movements or appropriate body should work with appropriate stakeholders at country level to ensure certification at lower cost and provide the organic agri-food processing sector with a funding opportunity

24. Facilitate access to industrial processing equipment ; Bring producers to scrupulously respect the requirements of organic production,
25. Identification and traceability of organic production

Way Forward for EA/OA in West Africa (Recommendations)

1. Mapping of gaps within organic and ecological agriculture in West Africa should be a continuous activity, in order to improve production in the sector.
2. Appropriate channels like the website of West African Organic Network (WAfrONet) – www.wafronet.bio could be used to consistently register stakeholders in the region.
3. Intensive education is needed for all stakeholders on importance of responding to survey tools like this.
4. Appropriate networking of stakeholders in different categories needed to encourage interactions among them that can lead to proper development of the organic and ecological agriculture sectors in the region

Development of national organic agriculture movements (NOAMs) should be encouraged across member countries of ECOWAS in order to encourage better networking among stakeholders of organic and ecological agriculture sectors in the region

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Union Namanegbzanga des Groupements Villageois de Tanlili (UNGVT) et l'Association Wend Raab de Toéghin (AWR).

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1. Contexte et problématiques

L'insécurité alimentaire affecte environ la moitié des ménages à faibles revenus avec une progression en zone urbaine. Les causes de l'insécurité alimentaire sont multiples: les problèmes de production qui affectent de manière inégale les villages des zones d'intervention de l'union UNGVT / Tanliliet de l'association Wend Raab de Toéghin, l'enclavement de certaines régions, les mauvaises pratiques alimentaires et la qualité du matériel semenciers disponible.

2. Méthodologie de sélection des semences paysannes

En 2002, un groupe de paysans chercheurs a été mis en place (GRA "Paspaogo ") par Union Namanagzanga des Groupements Villageois de Tanlili. Ce groupe devait réfléchir sur la problématique de la qualité des semences existantes dans leur localité et des localités voisines et y trouver des semences de qualité agronomique et nutritionnelle adaptées au niveau local. Les activités de la recherche ont commencé par la collecte des semences auniveau des villages de la région du plateau central etensuite les expérimentations en champ et sélections des meilleures et la dégustation pour s'assurer de la qualité nutritionnelle et potentialités de transformation en mets (repas).

3. Résultats obtenus

Les semences traditionnelles sélectionnées par les GRA
Les résultats obtenus par les GRA/OP sont les suivants :
-07 variétés de sorgho dont 06 variétés de sorgho blanc(Kengfo-menga,Manegmoogo»,Sâobonsgo, Sandakulii, Fiimiga, Gueteb-lagsda)et 01 variété de sorgho rouge (Basyiiré);-01variété de mil (Kazu-miiga).

NB : la sélection des variétés traditionnelles de sorgho et de mil a donné et donne de la satisfaction aux producteurs et consommateurs (*disponibilité, Accessibilité, rendement etapproprié pour divers types de transformation en mets ou repas très apprécié dans les milieux d'adoption)*

Tableau N°1: Les Variables/paramètres suivis pour la comparaison des variétés des GRA avec les variétés témoins de la recherche

Semences	Rendements	Grosseur et vitrosité du grain	Origine de la semence
Manegmoogo»	2960 kg/ha	normal	GRA/OP UNGVT de Tanlili
Kengfo-menga	2904 kg/ha	normal	
Bas-yiré	Non parvenu	normal	
Fiimiga	2800 kg/ha	normal	GRA/OP de l'Association Wend-Raab de Toèghin
Gueteb-lagsda	2410 kg/ha	normal	
Nongsooba(variété témoin del' INERA)	3309 kg/ha	normal	Station de recherche Saria : Variété témoin de la Recherche (INERA) en station

Les rendements milieu paysans sont :

Noms	"BASYIIRE"	" SANDAKUULI "	"MANEGMOOGO "	" KENGFO-MENGA "	"SÂOBONSGO"
Couleur du grain	Rouge	Blanc foncé	blanc	blanc	Blanc sale
Cycle	55 jours	58 jours	60 jours	70 jours	75 jours
Aires de culture (région)	Plateau central, Centre nord, Nord	Plateau central, Centre nord, Nord	Plateau central, Centre nord, Nord	Plateau central, Centre nord, Nord	Plateau central, Centre nord, Nord
Type de sol	argileux, basfond, caillouteux, sableux,	caillouteux, sableux	basfond, caillouteux,	basfond, caillouteux, sableux	Argileux, basfond, caillouteux,
Type de champ	- Champ de case - Champ de brousse	Champ de case	Champ de brousse	Champ de case	- Champ de case - Champ de brousse
Rendement potentiel	2 500 kg / ha	1 500 kg / ha	3 000 Kg / ha	3 000 Kg / ha	3 000 Kg / ha
Ravageurs et maladies principaux	Striga	Insectes et Oiseaux	Insectes	Insectes	Insectes
Longueur moyenne de l'épi	15 cm	15 cm	20 cm	30 cm	15 cm
Conservation en épis	2 ans	2 ans	2 ans	2 ans	2 à 3 ans
Ecartements	80 cm x et 40 cm	80 cm x et 40 cm	80 cm x et 40 cm	80 cm x et 40 cm	80 cm x et 40 cm
Démariage	3 à 4 pieds/poquet	3 à 4 pieds/poquet	3 à 4 pieds/poquet	3 à 4 pieds/poquet	3 à 4 pieds/poquet
Semis recommandé	- Après labour - en zaï	- Après labour - en zaï	- Après labour - en zaï	- Après labour	- Aprèslabour - en zaï
Période de semis	15 juin au 15 juillet	10 juillet au 04 Août	15 juillet au 04 Août	15 juin au 15 juillet	30 juin au 25 juillet

Quelques images des épis de semences traditionnelles

Image de site de production de Tanlili : Semence de sorgo rouge "Basyiire

+++ Image de site de production de Tanlili : sorgho blanc "Kengfo-menga " de Tanlili

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FEEDING THE WORLD WITHOUT POISONING

WAfrONet West Africa Organic Network

Organic Markets for Development (OM4D)

Antsa Razafimbelo

Project Coordinator
IFOAM – Organics International

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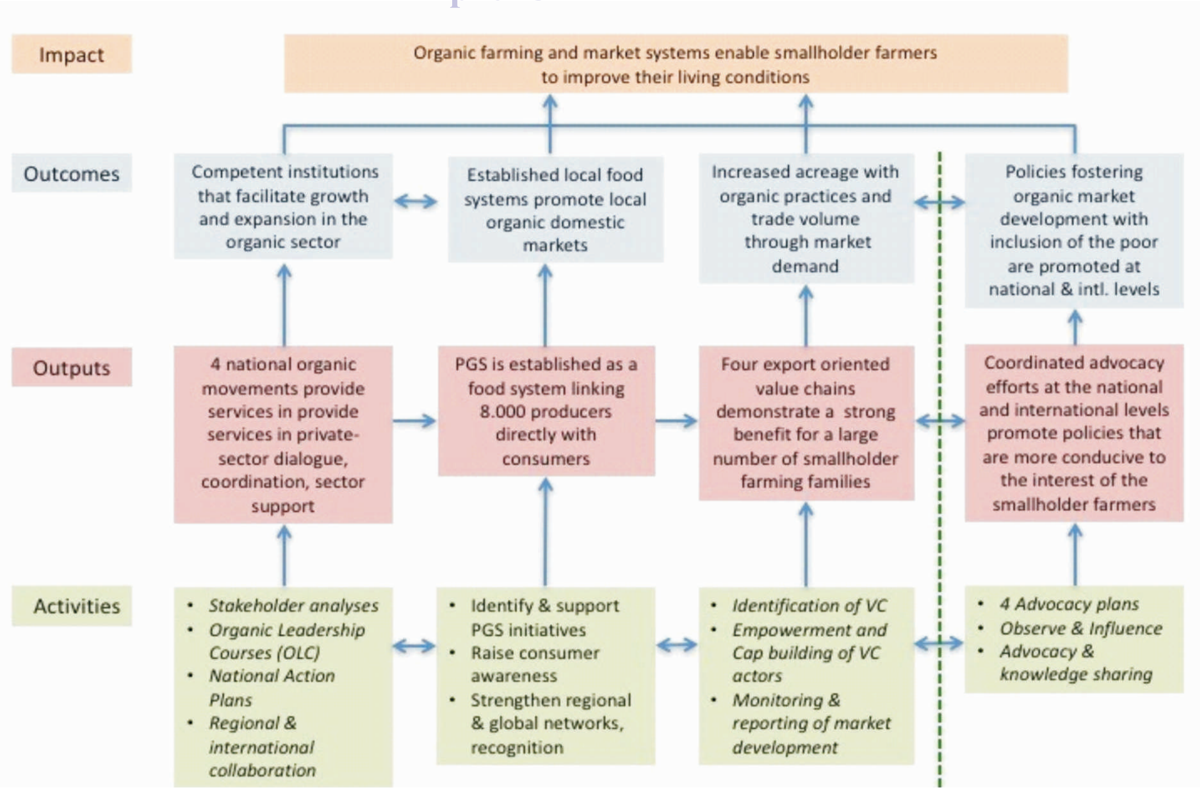
Project's overall goal:
Organic farming and related market systems should enable smallholder farmers to improve their living conditions

Donor: Ministry of Foreign Affairs Netherlands (BUZA)
Timeline: 11/2017 – 01/2022
Funding: 2,75 Mio Euro
Where: Burkina Faso, Togo, Ghana, São Tomé and Principe

Impact Chain



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Network of Organic Agriculture Researchers in Africa
RÉSEAU DES CHERCHEURS EN AGRICULTURE BIOLOGIQUE EN AFRIQUE
شبكة الباحثين في الزراعة العضوية بإفريقيا

Our achievements

Output 1: Four national organic umbrellas provide regular services in private-sector dialogue, coordination, sector support and other identified areas.

NAP — Draft NAPs available in Ghana, Burkina Faso, Togo. Finalisation approaching

OLC — Target 100 key persons. 82 leaders have benefited from the OLC. On average, 34% women participated in the courses.

WAOC 5 — Successful WAOC 5 organization and participation. Trade-related negotiations of project actors with key stakeholders involved in the production of organic inputs at the regional level: AMAP from Benin, GIE Bio Protect from Burkina Faso, and Organic Crop from Ghana. Trade relations ready

NOAMs — Continuous support for national movements in capacity development. NOAMs now operational in the 4 countries. Most recently, Movimento Bio - the movement in Sao Tomé & Principe founded. All 4 movements are now advancing the NAPs finalisation agenda.

Output 2: Participatory Guarantee System (PGS) is established as a food system linking producers directly with consumers

GH — PGS Ghana officially launched and a PGS Committee established. 19 producers newly certified since 2020 and 4 others in transition.

BF — National PGS expading in Burkina Faso. 549 producers now certified, with 72 men and 477 women, representing a surface of 146.5 ha.

TG — 4 different PGS initiatives in place and supported. Representing a total of 518 producers specialized in various activities (seed production, market supply, vegetable production).

STP — National PGS in place covering 8 communities of horticulturists that have representatives in the national PGS committee.

The number of trained producers in total is 1, 842. 567 are already certified

Consumer awareness raising, and market access improvement: in Ghana, SowGreen, a farm that has its own organic market channel is now selling PGS-certified products weekly and through placed orders. A PGS market restarted in Accra after a break due to COVID-19.

In Togo, Expert 25, one of the PGS pilots in Togo has started a weekly market in Lomé and is very active in promoting its market (now called: Marché des fruits et legumes bio de Lomé). The AMAP initiative has established a marketing system.

Output 3: Four export-oriented value chains demonstrate a strong benefit for a large number of smallholder farming families.

More than 142 VC actors have been directly trained by OM4D in ICS and VC development

GH	**2 trained VC coaches have trained 14 field officers in 7 communities**
BF	**4 VC coaches have been trained and are active**
TG	**3 VC coaches have been trained**
STP	**6 VC coaches have been trained**

The project supported the participation of 16 primary stakeholders (8 pineapple producers, and 8 sheanut farmers) to the WAOC 5 in Ghana.

In Ghana, 20 new buyers are interested, and the harvesting and drying of organic cassava is underway for an early 2021 marketing. It will be possible for the supported farmers to grow organic cassava on their organic fields during the next cropping calendar.

In Burkina Faso, other potential buyers such as the company SFC, the main buyer of organic shea nuts in the region, have been identified, and with which a promising relation has been established. SFC may open the door to USA and EU cosmetics markets. This is an ongoing process.

Output 4: Coordinated advocacy efforts at the national and international levels promote policies that are more conducive to smallholder farmer interests.

In Ghana, advocacy work has been carried out and are showing promising results in ensuring favourable attitude of government agencies towards PGS Ghana.

In Burkina Faso and Togo, the NAPs are reaching finalisation stages.

At the global and regional levels, lobbying actions with key global stakeholders on the EU to influence the new regulations on group certification led the EU to consider IFOAM-Organics International's recommendations on the size of the groups.

In Sao Tomé & Principe, a MoU entitled "100% Organic Sao Tome and Principe" signed on 22 May 2020 by the Ministry of Agriculture and the OM4D project. This PPP protocol aims at guaranteeing the food and nutritional security of the country through production of nutritious and quality food for local and export markets.

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Jute Mallow Performance as Affected by Rock Phosphate Application and Arbuscular Mycorrhizal Inoculation in South-West Nigeria

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Abstract

Low crop yields are generally associated with land degradation resulting from continued crop cultivation without adequate measures to replace the mined soil nutrient in Nigeria. Jute mallow is a heavy feeder on phosphorus and locally available Sokoto phosphate rock (with a little detrimental effect on soil health and crop quality) could be a cheap P source for sustaining soil fertility for vegetable production. However, they are slow in nutrient release, hence the need for solubilizing bacteria for enhanced crop performance from RP application. Therefore, the effects of Sokoto phosphate rock and or Arbuscular Mycorrhizal Fungi (AMF) were evaluated on the performance of jute mallow at the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. In a repeated pot experiment, soil amendments involving AMF inoculation, rock phosphate (RP) at 30 kg P_2O_5, AMF+RP and control, were evaluated on three varieties of jute mallow (Amugbadu, Eleti-eku and Oniyaya) in a completely randomised design with five replicates. The three varieties under control recorded significantly ($P<0.05$) lower fresh and dry biomasses compared to the other treatment combinations. However, the highest fresh and dry weight in both experiments was produced by plants of Eleti-eku variety treated with AMF+RP. Also, AMF+RP treatment significantly improved mycorrhizal infection in jute mallow root compared to RP application and the control Eleti-eku variety had significantly higher mycorrhizal root infection than Oniyaya variety, but similar to Amugbadu in both cropping periods. Application of RP and AMF+RP significantly ($P<0.05$) improved Amugbadu and Oniyaya fresh biomasses compared to the mean values of their controls. Residual soil chemical properties showed a significant ($P<0.05$) increase in N and available P with the application of AMF+RP and AMF inoculum, respectively, under Amugbadu. Application of AMF inoculation with RP to Eleti-eku appeared optimum for jute mallow cultivation in Southwestern Nigeria than there sole application.

Performance de la mauve juteuse affectée par l'application de phosphate naturel et l'inoculation de mycorhizes arbusculaires dans le sud-ouest du Nigeria

Résumé

Les faibles rendements des cultures sont généralement associés à la dégradation des terres résultant de la poursuite des cultures sans mesures adéquates pour remplacer les éléments nutritifs du sol minés au Nigéria. La mauve de jute est un gros consommateur de phosphore et la roche phosphatée de Sokoto disponible localement (avec un léger effet néfaste sur la santé du sol et la qualité des cultures) pourrait être une source de phosphore bon marché pour maintenir la fertilité du sol pour la production de légumes. Cependant, ils libèrent lentement les nutriments, d'où la nécessité de solubiliser les bactéries pour améliorer les performances des cultures à partir de l'application de RP. Par conséquent, les effets de la roche phosphatée de Sokoto et/ou des champignons mycorhiziens arbusculaires (AMF) ont été évalués sur les performances de la guimauve juteuse au Département d'agronomie de l'Université d'Ibadan, Ibadan, Nigeria. Dans une expérience répétée en pot, des amendements de sol impliquant l'inoculation d'AMF, du phosphate naturel (RP) à 30 kg de P2O5, de l'AMF+RP et un témoin, ont été évalués sur trois variétés de jute mauve (Amugbadu, Eleti-eku et Oniyaya) dans un dispositif complètement randomisé. avec cinq répétitions. Les trois variétés contrôlées ont enregistré des biomasses fraîches et sèches significativement ($P<0,05$) plus faibles par rapport aux autres combinaisons de traitement. Cependant, le poids frais et sec le plus élevé dans les deux expériences a été produit par les plantes de la variété Eleti-eku traitées avec AMF + RP. En outre, le traitement AMF + RP a significativement amélioré l'infection mycorhizienne dans la racine de mauve juteuse par rapport à l'application de RP et la variété témoin Eleti-eku avait une infection mycorhizienne des racines significativement plus élevée que la variété Oniyaya, mais similaire à Amugbadu dans les deux périodes de culture. L'application de RP et AMF + RP a amélioré de manière significative ($P <0, 05$) les biomasses fraîches d'Amugbadu et d'Oniyaya par rapport aux valeurs moyennes de leurs témoins. Les propriétés chimiques résiduelles du sol ont montré une augmentation significative ($P<0,05$) de N et de P disponible avec l'application d'inoculum AMF + RP et AMF, respectivement, sous Amugbadu. L'application de l'inoculation d'AMF avec RP à Eleti-eku a semblé optimale pour la culture de la mauve de jute dans le sud-ouest du Nigeria par rapport à la seule application.

Mots-clés:
Infection mycorhizienne des racines, Phosphate de roche, Variétés de mauve juteuse, Effet résiduel

Introduction

Phosphorus (P) is an element widely distributed in nature and occurs as a primary constituent of plant and animal life. It is the second most important plant nutrient (after nitrogen) essential for proper plant growth and development. The nutrient plays a function in energy transfer in metabolic pathways of biosynthesis and is a structural component of nucleic acids in plants (Reetz, 2016). Plants deficient in P exhibit retarded growth following reduced cell and leaf expansion, rates of respiration and photosynthesis (Hellal *et al*., 2019). Soils in the tropics are predominantly acidic and often P deficient with high P sorption (fixation) capacities (Morris *et al*., 2007). This problem aggravates when harvested crop biomasses (such as leafy vegetables) from the field are consumed. Therefore, required substantial P replenishment for sustainable crop production (Moyin-Jesu, 2008).

Attempt to replenish the lost P have resulted in the use of chemically formulated fertilisers, such as triple super phosphate and single super phosphate and other compound fertiliser formulations, which are considered inappropriate for use in vegetable production (Aderinoye-Abdulwahab and Salami, 2017; Paul and Bester, 2020). Some of the acclaimed challenges were high cost, high rate of P fixation in the soil, deterioration of soil health and most importantly, reduction in the quality of traditional leafy vegetables like jute mallow (*Corchorus olitorius* L.), which is a heavy feeder on soil nutrients (Weinberger and Msuya, 2004; Kate *et al*., 2020). Consequently, research is interested in searching for a sustainable alternative that will help in reducing foreign exchange spending through the importation of these fertilisers, increase soil health, and improve crop quality. The application of organic sources of P through crop residues and animal manures has been reported to improve crop performance (Azeez and Van Averbeke, 2010; Schröder *et al*., 2010). However, they are bulky and not readily available in sufficient quantity to meet the need of farmers (Amjad *et al*., 2016). Hence, the need to evaluate locally available phosphate of rock that is high in quality and considered economically extractable to improve soil P status. Although, poultry supplies P manure more readily to plants than other organic *manure* sources (Garg and Bahla, 2008), nevertheless, their interaction with RP further improve maize and cowpea performances (Akande and Oluwatoyinbo, 2005).

In Nigeria, deposits of highly concentrated phosphate rocks are found in Sokoto, Abia, Imo, Edo, Anambra, and Ogun States (Ministry of Solid Minerals Development, 2000). The deposit of PR across the country was reported to be 40 million metric tonnes. (Ministry of Solid Minerals Development, 2000)The exploitation of the abundantly available phosphate rock is likely to be an acceptable and sustainable alternative to chemically formulated P, for environmental and economic preferences to improve crop yield and quality. Although, they may contain accessory minerals and impurities (UNIDO and IFDC, 1998). However, their use to improve crop production has been well documented in tomatoes, cabbage (Minja*et al***.,** 2014) and carrots (Mwangi *et al*., 2020). Studies have shown the inadequacies of RP in P nutrient use efficiency by crops compared to the chemical sources of P (IAEA, 2002). Direct application of RP to the soil result in the slow release of P_2O_5 to meet the needs of a growing crop due to its poor water solubility (Reetz, 2016). The use of inoculation with arbuscular mycorrhizal fungi, P-efficient plant genotypes, phosphate solubilizing micro-organisms, and phospho-composting are means of improving the availability of the nutrients within the short period of the crop cycle (McDonald *et al*., 2013; Nacoon *et al*., 2020).

Arbuscular mycorrhizal fungi (AMF) are soil-borne fungi that help transfer some of the essential plant nutrients (particularly P) to the plant roots and receive carbohydrates from the root of the plant (Aliasgharzad *et al*., 2009). However, AMF colonization of plants and mycorrhizal soil infectivity are altered by both mineral and organic P fertilisers (Lakshmipathy *et al.,* 2007). Information on the use of AMF colonization in enhancing Sokoto RP for short-duration crops like jute mallow is scanty. Therefore, the objective of this study was to evaluate the effects of AMF inoculation and phosphate rock on three varieties of jute mallow.

Materials and Methods

The experiment was conducted between the months of February and April 2018 in the screen house of the Department of Agronomy, University of Ibadan, Ibadan, Nigeria, (7°27'05.5''N and 3°53'31.0''E).

Experimental design and treatments

The experiment consisted of two factors namely: four soil amendments (control, AMF (*Glomus mossea*) inoculation, Phosphate rock, and AMF+PR) and three varieties of *Corchorus olitorius* (namely, Amugbadu, Eleti-eku and Oniyaya). The two factors were arranged in a 4 × 3 factorial arrangement in a completely randomised design with five replicates. The study was also repeated in the same year after the first evaluation. The treatments evaluated were; Control + Amugbadu, Control + Eleti-eku, Control + Oniyaya, AMF + Amugbadu, AMF + Eleti-eku, AMF + Oniyaya, RP + Amugbadu, RP + Eleti-eku, RP + Oniyaya, AMF+RP +Amugbadu, AMF+RP + Eleti-eku, AMF+RP + Oniyaya. There were 12 treatments in each replicate, making a total number of 60 pots filled with 5kg soil.

Soil sample collection

Soil samples depleted in nutrient status were collected at a depth of 0-15 cm and bulked for the screen house experiments from Parry Road, University of Ibadan, Ibadan, Nigeria. The bulked samples were air-dried and sieved through a 2 mm mesh to remove gravel and debris before taking the sampled soil for routine laboratory analyses for the physical and chemical properties as described by IITA (1982) manual. The results of the soil analysis were as shown in Table 1. The soil textural class was loamy sand.

Table 1: The properties of soil used in the evaluation of rock phosphate under screen house condition

pH	Organic C	N	Av. P	Ca	Mg	K	Na	Exch. Acidity	Mn	Fe	Cu	Zn	Particle size			Fungal Count	Bacterial Count
(H_2O)	(g/kg)	(g/kg)	(mg/kg)						cmol/kg				Sand	Silt	Clay	(x105 cfu/g soil)	
6.5	7	1	0.5	0.4	0.3	0.1	1	0.1	86	80	1.5	1.2	858	72	70	2.02	5.09

The RP contained no organic C and total N, while total P_2O_5, CaO, $CaCo_3$ and MgO were 32.50, 44.23, 79 and 0.95%, respectively. Also, Fe_2O_3, Al_2O_3, SiO_2 and Cd were respectively 2.19, 1.79, 4.20 and 0.63% as reported by Akinrinde and Obigbesan (2005).

Treatment application

Pots assigned AMF treatments were inoculated with 5 g *Glomus mossea,* and 0.038 g (at the recommended dose of 30 kg/ha) of Sokoto rock phosphates fertiliser were applied to the pots that were assigned PR by incorporating them into the soil before seedling transplanting. Both amendments were sourced from the Department of Agronomy,

The three varieties of *Corchorus olitorius* were Amugbadu, Eleti-Eku, and Oniyaya sourced from the National Horticultural Research Institute (NIHORT), Ibadan. The characteristics of these varieties are explained by Ajayi *et al*. (2019). They were all transplanted at 3 weeks after sowing in the nursery. Weeding was manually done as and when due, while watering was done at a day interval throughout the study.

Data collection

Plant height, the number of leaves, leaf area and fresh biomass was recorded at 8 WAP. Dry biomass was obtained after the plant samples were oven-dried and the dry weight of shoots was measured using a weighing-scale (using Camry digital kitchen scale, model EK5055). Soil samples were collected for the determination of mycorrhizal infection count and, chemical analysis of the soil after which the experiment was assessed for residual nutrients before repeating the study.

Data analysis

All data collected were subjected to ANOVA using SAS 9.4, and means of significant treatments were separated using Duncan Multiple Range Test at a 0.05 probability level for both main effects and interactions.

Results

Varietal responses of jute mallow to soil amendments

Varietal growth and yield responses of jute mallow to soil amendments are presented in Table 2. The effects of soil amendments on the varieties were similar but differed significantly ($P<0.05$) among the treatments in both experiments. The jute mallow varieties under control had the lowest plant height, while the AMF inoculated + RP applied plants had the highest mean height for Amugbadu and Oniyaya. The mean heights of Eleti-eku with soil amendments were consistently higher across the soil-amendments. Similarly, the number of leaves was significantly ($P<0.05$) affected by the treatments, with the lowest mean values of both croppings observed in the control under the Oniyaya variety, while AMF inoculated Eleti-eku variety produced the highest number of leaves. Leaf area was not significantly ($P<0.05$) affected by soil amendments and variety interaction in the first experiment, but showed significance in the residual effect study. The three varieties under control produced significantly (P<0.05) lower fresh biomass compared to the other treatment combinations. However, the treatment involving AMF+RP with Eleti-eku recorded the highest fresh biomass in both experiments. A similar trend was recorded for fresh biomass accumulation in both experiments.

Jute mallow height was significantly (P<0.05) increased following the application of soil amendments compared to the control in both experiments, except for the AMF inoculated plants in the second experiment where AMF inoculation was at par with the control (Table 2). The application of AMF, PR and their combination significantly (P<0.05) improved the number of leaves in jute mallow in the first cropping, while no significant difference was observed among the treatments in the second experiment. A significant increase in leaf area was observed in plants treated with PR and AMF+PR compared to the control; however, the increase was not significantly different from the AMF inoculated plants. The application of soil amendments significantly enhanced fresh biomass in the two cropping of jute mallow, with the highest significance observed with the combined application of AMF+PR compared to the other treatments. Similarly, AMF+RP application significantly increased dry biomass in jute mallow compared to the other treatments. The order of significant increases in jute mallow dry biomasses was AMF+RP > RP > AMF > control.

Table 2: Responses of different jute mallow varieties to soil amendments at harvest in two cropping periods

Treatments	Plant height (cm)		Mean	No. of leaves		Mean	Leaf area (cm^2)		Mean	Fresh biomass (g)		Mean	Dry biomass (g)		Mean
	1	2		1	2		1	2		1	2		1	2	
Soil amendments															
S1	51.00b	68.73b	59.87	50.33b	71.40	60.87	215.44b	264.65	240.24	11.83d	11.34d	11.58	3.87d	5.00d	4.43
S2	69.40a	69.93b	69.67	64.20a	76.73	70.47	478.97ab	375.22	427.10	24.68c	22.70c	23.70	7.30c	8.55c	7.93
S3	66.47a	80.00a	73.23	71.33a	75.87	73.60	529.23a	369.45	449.32	29.40b	29.65b	29.52	9.77b	11.73b	10.75
S4	66.00a	81.53a	73.77	71.13aa	73.20	72.17	511.91a	347.60	429.78	32.55a	37.70a	35.13	12.83a	14.80a	13.82
SE	2.50	1.99		2.41	2.03		99.19	40.41		0.94	1.87		0.10	0.14	
Variety															
V1	64.00	76.10	70.05	50.33b	71.40	68.20	402.76	330.42	366.60	21.78b	21.73b	21.76	7.33c	8.80c	8.28
V2	63.90	74.55	69.23	64.20a	76.73	73.08	539.95	352.71	446.48	25.69a	27.82a	26.75	9.55a	11.52a	10.10
V3	61.75	74.50	68.13	71.13aa	73.20	66.55	358.95	334.56	346.76	26.38a	26.50a	26.44	8.44a	9.75b	9.32
SE	2.17	1.73		2.26	1.78		83.31	34.99		0.82	1.62		0.09	0.12	
Interactions															
S1 x V1	51.40cd	73.60b-e	62.50	44.40f	77.20ab	60.80	204.4	268.76bc	236.58	10.93e	11.53e	11.23	3.23e	4.19e	3.71
S1 x V2	49.00d	65.20e	57.10	56.60d-f	71.20ab	63.90	238.2	216.14c	227.77	12.11e	11.73e	11.92	4.51e	5.81e	5.16
S1 x V3	52.60b-d	67.40de	60.00	50.00ef	65.80b	57.90	203.71	309.05a-c	256.38	12.45e	10.74e	11.60	3.86e	5.01e	4.43
S2 x V1	71.40a	68.20de	69.80	61.60b-e	75.40ab	68.50	458.38	377.85a-c	418.15	19.65d	18.88de	19.27	6.02de	7.04de	6.53
S2 x V2	73.40a	72.60b-e	73.00	69.20a-d	80.40a	74.80	659.63	472.07a	565.85	25.67c	21.14cd	23.41	8.16cd	10.03b-d	9.10
S2 x V3	63.40a-c	69.00c-e	66.20	61.80b-e	74.40ab	68.10	318.89	275.73a-c	297.31	28.72c	28.09b-d	28.41	7.71de	8.58de	8.15
S3 x V1	66.40a	81.40ab	73.90	80.00a	75.20ab	77.60	538.7	328.16a-c	433.43	30.18bc	29.77bc	29.97	9.76cd	11.71bc	10.74
S3 x V2	66.00a	81.60ab	73.80	76.00ab	76.20ab	76.10	646.6	350.99a-c	498.75	27.90c	29.05bc	28.47	9.01cd	10.77b-d	9.89
S3 x V3	67.00a	77.00a-d	72.00	58.00d-f	76.20ab	67.10	402.38	429.20ab	415.79	30.13bc	30.13bc	30.13	10.52b-d	12.72bc	11.62
S4 x V1	66.80a	81.20ab	74.00	59.60c-e	72.20ab	65.90	409.56	346.91a-c	378.25	26.38c	26.74cd	26.56	11.07bc	13.18bc	12.13
S4 x V2	67.20a	78.80a-c	73.00	80.00a	75.00ab	77.50	615.37	371.64a-c	493.55	37.06a	49.35a	43.21	14.99a	17.52a	16.26
S4 x V3	64.00ab	84.60a	74.30	73.80a-c	72.40ab	73.10	510.81	324.27a-c	417.54	34.21ab	37.02b	35.61	12.44bc	13.71bc	13.08
SE	4.33	3.46		5.1	4.07		166.62	69.99		1.63	3.24		0.99	0.95	

S1 = Control; S2 = AMF inoculation; S3 = Rock Phosphate; S4 = AMF inoculation + Rock Phosphate; V1 = Amugbadu; V2 = Eleti-eku; V3 = Oniyaya;In a column, figures with same letter(s) or without letters do not differ significantly, while figures with dissimilar letter differ significantly according to DMRT at 5% level of probability

No significant varietal effect was recorded in the two croppings. The Eleti-eku variety produced the highest number of leaves and was significantly (P<0.05) higher than the number of leaves produced by the other varieties. The highest and lowest were left out once the treatments were not significant. Eleti-eku and Oniyaya varieties of jute mallow were significantly (P<0.05) different from Amugbadu with respect to fresh biomass in the two croppings. Similarly, Eleti-eku and Oniyaya varieties had significantly higher dry biomasses compared to Amugbadu in the first cropping on jute mallow. However, in the second cropping, the dry biomass for the Eleti-eku variety was significantly higher than Oniyaya, which was also higher than the control as shown in Table 2.

Effects of soil amendments on mycorrhizal root infection

The mycorrhizal root infection was significantly higher in the inoculated plants compared to the other soil amendment treatments in both croppings (Figure 1). Similarly, the combined application of AMF and RP improved mycorrhizal infection in the root of jute mallow than sole RP application, which also enhanced AMF infection by 39.26 % and 19.09 % compared to the control in the first and second cropping, respectively.

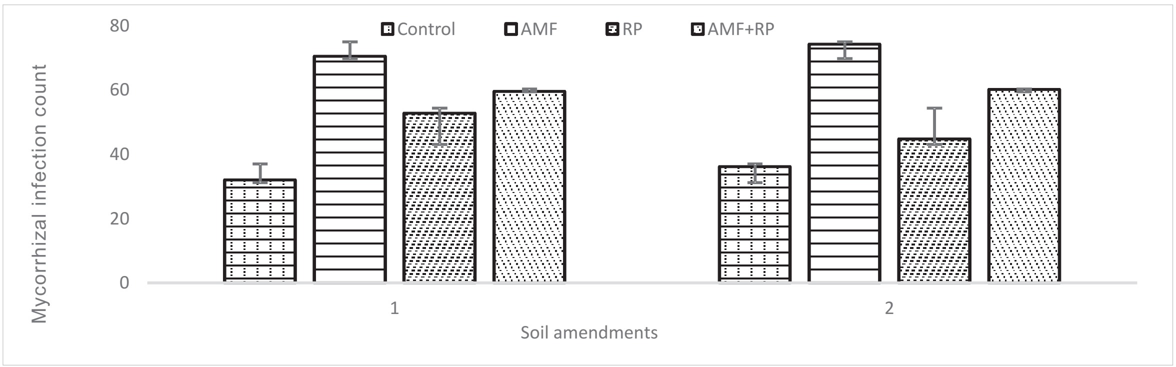

Figure 1: Effects of soil amendments on mycorrhizal infection in Jute mallow in two cropping periods (AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate, ns = Not significant at $P < 0.05$ level)

Varietal response to mycorrhizal infection differed among varieties of jute mallow under study (Figure 2). The Eleti-eku variety showed higher root infection than the other varieties in both cropping, while Amugbadu and Oniyaya were the lowest in mycorrhizal root infection in the first and second cropping, respectively.

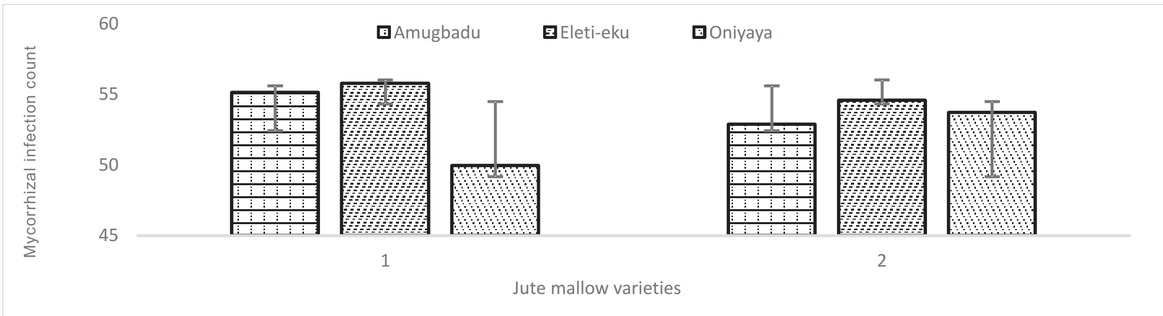

Figure 2: Response of jute mallow varieties to mycorrhizal colonization in two cropping periods

The influence of soil amendments on mycorrhizal infection varied among jute mallow varieties ((Figure 3). Root infection with mycorrhiza was lowest for all the varieties under control in both croppings. However, the highest mycorrhizal root infection for Amugbadu, Eleti-eku and Oniyaya were under mycorrhizal inoculation treatments for both cropping periods. Furthermore, the combined application of AMF+RP improved mycorrhizal root infection compared to the control in the two cropping periods.

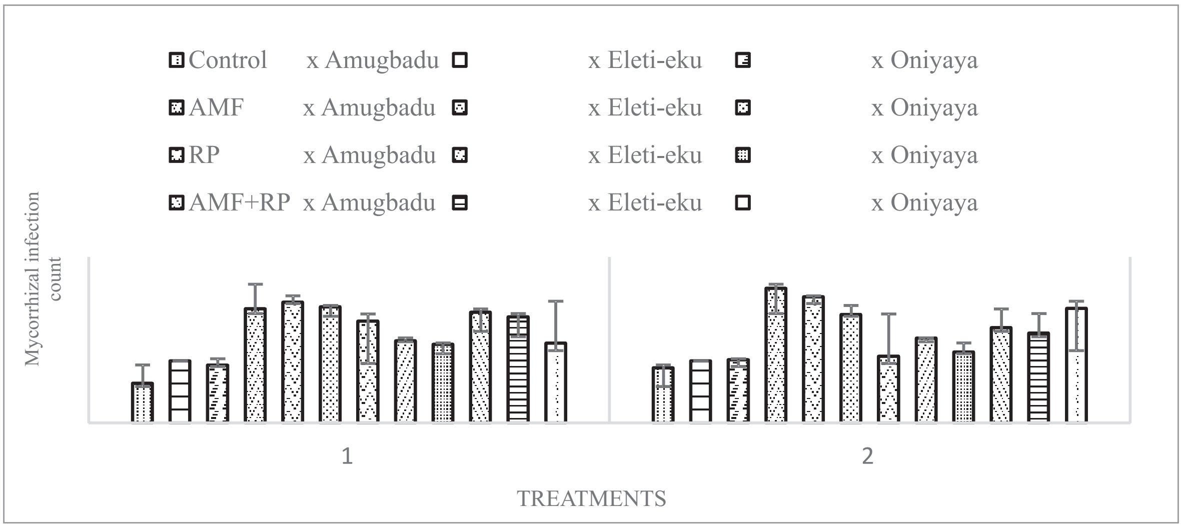

Figure 3: Interactions of soil amendments and jute mallow on mycorrhizal infection in two cropping periods (AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate, ns = Not significant at P < 0.05 level)

Residual soil nutrients as influenced by soil amendments applications and jute mallow varieties

The combined effects of soil amendments and jute mallow varieties indicated that there were significant variations among the treatments with respect to soil pH after jute mallow harvest (Table 3), however, the lowest was observed after RP with Eleti-eku treatment. After treatment imposition, the OC did not differ significantly, however, OC under control with Oniyaya and AMF inoculated Amugbadu had the lowest and highest values, respectively. The observed N content after harvest showed that AMF+RP with Amugbadu had significantly higher N leftover compared to RP with the Oniyaya treatment, while the other treatments were similar. The available P that was found in the soil after harvest was significantly higher under AMF inoculated Amugbadu compared to RP with Eleti-eku, AMF+RP with Amugbadu and AMF+RP with Eleti-eku treatments. The K available in the soil before the residual trial revealed that the concentration varied significantly among treatments and the highest and lowest values were observed under control with Eleti-eku and control with Oniyaya, respectively. Similarly, Ca concentration in the soil after harvest indicated significant variation among treatments and ranges from 0.84 - 3.62 Cmol/kg in AMF+RP with Amugbadu and AMF with Eleti-eku, respectively. A significant increase of Mg in the soil after harvest was observed from AMF with Eleti-eku plots compared to AMF and RP amendments with Amugbadu and Oniyaya plots. Post-harvest chemical properties of soil as influenced by soil amendments and jute mallow varieties interactions.

Table 3: Influences of soil amendments and jute mallow varieties interactions on residual soil nutrients

Treatments	pH	Organic C (g/kg)	N (g/kg)	Av. P (mg/kg)	K (Cmol/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)
Soil amendments							
Control	7.14	9.95	0.62	33.3	0.69	1.48	1.53
AMF	7.19	14.42	0.67	71.6	0.73	2.40	1.85
RP	7.07	14.34	0.67	49.3	1.01	1.34	1.30
AMF+RP	7.20	12.95	0.72	46.4	1.16	1.65	1.79
SE	0.03	1.04	0.02	7.95	0.11	0.24	0.13
Variety							
Amugbadu	7.32	13.16	0.70	52.95	0.80	1.23	1.42
Eleti-eku	6.88	12.10	0.67	49.83	1.05	2.21	1.99
Oniyaya	7.25	13.49	0.64	47.68	0.84	1.72	1.46
SE	0.14	0.42	0.02	1.53	0.08	0.28	0.18
Interactions							
Control x Amugbadu	7.61a	9.25	0.62ab	31.1ab	0.52ab	1.26ab	1.77ab
x Eleti-eku	7.15ab	11.66	0.58b	20.4b	1.33a	2.13ab	1.62ab
x Oniyaya	6.66ab	8.93	0.67ab	48.4ab	0.21b	1.05b	1.21b
AMF x Amugbadu	6.88ab	18.24	0.64ab	106.2a	1.00ab	1.84ab	1.23b
x Eleti-eku	7.31ab	10.28	0.72ab	80.1ab	0.37ab	3.62a	3.04a
x Oniyaya	7.39ab	14.75	0.64ab	28.5b	0.82ab	1.74ab	1.28b
RP x Amugbadu	7.44ab	12.45	0.65ab	53.7ab	0.53ab	0.98b	1.12b
x Eleti-eku	6.42b	16.84	0.77ab	74.7ab	1.28a	1.19b	1.46ab
x Oniyaya	7.35ab	13.72	0.59b	19.5b	1.22a	1.86ab	1.32b
AMF+RP x Amugbadu	7.35a	12.68	0.89a	20.8b	1.16ab	0.84b	1.54ab
x Eleti-eku	6.64ab	9.61	0.62ab	24.1b	1.22a	1.88ab	1.82ab
x Oniyaya	7.61a	16.55	0.64ab	94.3ab	1.09ab	2.22ab	2.01ab
SE	0.34	3.87	0.09	26.24	0.33	0.8	0.58

AMF = Arbuscular mycorrhizal fungi; RP = Rock phosphate, In a column, figures with the same letter(s) or without letters do not differ significantly, while figures with dissimilar letters differ significantly according to DMRT at 5% level of probability.

The effects of soil amendments after jute mallow cultivation on the average soil chemical properties after planting from both cropping indicated that the soil pH was within the neutral values with no significant difference among the soil amendment treatments (Table 3). The lowest residual organic carbon (OC) was observed in the control while no appreciable difference was observed between the highest from AMF and RP treatments. Similarly, residual soil pH and nutrients were not significantly affected by the cultivation of jute mallow. However, the value was highest under the cultivation of the Amugbadu variety of jute mallow, while the lowest was under Eleti-eku cultivation.

Discussion

The pH of the soil used in the study was within the range (5.8 - 6.5) considered appropriate for the production of most vegetable crops. The soil nutrient status before the experiment was moderately adequate for a good performance of jute mallow- except for P content as recommended by Fasinmirin and Olufayo (2009) for good yield. Hence, the response of the crop to the application of P source or means of enhancing P uptake will be appreciable (Morgan and Connolly, 2013). Similarly, the soil textural (loamy sand) will not adequately encourage the availability of P; therefore, it will likely respond favourably to organic amendments. The soil used in the study was moderately poor in fungi and bacterial count according to

Malik *et al*. (2016). It may require amelioration with introduced inoculum to promote root colonization by AMF (Gianinazzi-Pearson *et al.,* 1985; Maiti *et al.*, 2011).

The results indicated that jute mallow performance enhancement was through the application of soil amendments. Application of RP, AMF inoculation and AMF+RP enhanced the availability of most soil nutrients to the crop as revealed in the residual soil analysis. The improvement that resulted from amendments application implied that AMF inoculation, RP and their combination improved plant nutrient uptake, which concomitantly, enhanced plant height, number of leaves and leaf area in the study. The observed increase in jute mallow fresh and dry biomasses due to AMF inoculation than the control is associated with the introduced mycorrhizal mycelia in the root of jute mallow in acquiring nutrients that ordinarily were unavailable to the root system of the uninoculated plants. Hence, the introduced AMF inoculation was likely to be more effective than the indigenous AMF in the jute mallow growth stimulation as observed in the study. Ortas (2015) and Zaine *et al*. (2017) reported similar results. These improvements were achieved when the plant supplies the fungi with sugars that were produced by photosynthesis, while the hyphae network increased the capacity of the plant to absorb water and improves nutrients (Roy-Bolduc and Hijri, 2011). However, because the most limiting nutrient as revealed in the soil analysis was P, it implied that the addition of P through RP application was able to meet the demand of the plant for P. Similarly, the better performance in the plants treated with AMF+RP suggests that the use of RP was inadequate in meeting the P need of the plant and that the support of AMF inoculation further enhanced the uptake of the nutrient aside from other function. This finding supports the report of Youssef *et al*. (2017) that the combined application of AMF with RP improved the growth of snap beans compared to RP alone. The reason was attributed to the improvement in the supply of phosphorus which increases the root-shoot ratio and increases the growth of lateral roots resulting in the ability to absorb more water and a higher concentration of mineral nutrients from the soil. This was reflected in the higher OC found in the residual soil nutrient analysis. Also, the accompanying nutrients in the RP facilitate' nutrient utilization, which contributed to the increase in the growth of jute mallow.

The varietal differences in growth and yield indicated that the Amugbadu had the lowest growth attributes among the varieties used in the study. However, Eleti-eku was better or the best among the three varieties. However, the varieties were not different in height and leaf area. The differences in fresh and dry biomasses showed that the variety with more biomass is appreciated in the market than the lighter varieties in weight.

The variation in the response of different varieties of jute mallow to soil amendments suggested that the ability to acquire nutrients from the soil differs among varieties of crops. The results reconciled with McDonald *et al*. (2013) that crop species may vary in their genetic efficiency for the acquisition and utilisation of nutrients for growth improvement. The observed varietal differences to soil amendment indicated that the lowest response was in Amugbadu across amendment applications, while Eleti-eku did better, with the highest response observed with the application of AMF+RP. The Amugbadu and Oniyaya varieties of jute mallow also performed better under the application of AMF+RP. However, the least of the response observed in the Amugbadu indicated a poorer response to the nutrient applied. Hence, the applied amendments were able to mitigate the deficiency symptoms exhibited through retarded growth succeeding reduced cell and leaf expansion, and lower rates of respiration and photosynthesis in plants (Hellal *et al*., 2019).

Jute mallow plants' roots were colonized by AMF in all treatments in the experiment. However, the mycorrhizal root infection increase observed in the inoculated plant than the uninoculated suggests that the introduced inoculum was more efficient in colonizing the plant root than the native mycorrhizal. Likewise, the introduced mycorrhizae resulted in the enrichment of the native mycorrhizal potential in the soil. Thereby, increasing the mycorrhizal root infection of jute mallow than the control. This result corroborates the report by Zaine *et al*. (2017) on the levels of root colonization in tomato. Furthermore, the response observed with RP application in mycorrhizal root infection increase is attributed to the supply of nutrients contained in the RP that helps to nourish the plant root thereby, increasing the surface area for the native mycorrhizal infection. However, the reduction in mycorrhizal root infection observed in the combined AMF inoculation with RP is well documented that plant root responses to AMF colonization is usually positive when P is limiting (Lakshmipathy et al., 2007). However, with the adequate supply in P, the contribution of AMF inoculation diminishes, thereby resulting in a decrease in mycorrhizal root infection. This finding was commemorated by Liu *et al*. (2016) report that a reduction in AMF infection levels in root tissues with the increase in the application of P. The plant dependents on mycorrhizal mycelia reduce under adequate P supply. Hence, the carbohydrate translocated to the root for mycorrhiza multiplication is used by the plant for growth (Aliasgharzad *et al*., 2009).

The residual soil nutrients from the different soil amendments indicated no differences in the left-over. However, the residual nutrients were lower in the control, implying that after the harvest, more nutrients have been mined from the soil. A similar observation was reported by Uko *et al*. (2020) that the application of AMF increased soil pH. The reduction in the OC, N, P and K in the control confirmed the inadequacy of these nutrients in sufficient quantity to support jute mallow growth. Hence, this leading to lower performance as observed in the result. The improvements in residual soil nutrient in OC, available P and Ca with AMF inoculation treatment indicated, was supported by Uko *et al*. (2020) report. These residual soil nutrients were likely to be those trapped in the mycorrhizal mycelia about to be made available to the crop or the succeeding crop. This is particularly true as the values of these residual soil nutrients in the AMF+RP were comparatively lower than those observed in the AMF inoculated pots. Similarly, in the AMF+RP treatment, the decreased residual soil nutrient most implies that the plants have adequately mined the nutrients for improved growth as indicated in the results. Furthermore, the increase in OC observed with the application of RP is associated with the effects of P in improving the crop root length network for acquiring nutrients, thereby possibly increasing the allocation of OC to the root system in the soil for development(Tsozue, 2021).

Even though the residual soil pH was within an appropriate range for plant development, the residual soil pH under Eleti-eku was most appropriate. The high residual soil nutrients for N and available P under the Amugbadu suggests either that the plant variety is relatively limited in its capacity to take up the nutrients from the soil or that the nutrients were not adequately supplied in time for their uptake. These probably explained the lower performances observed in the variety (Mengel and Kirkby, 2001; Morgan and Connolly, 2013). However, the lower response from the performance in the Oniyaya variety compared to residual soil nutrients consequently suggest a low utilization rate of the acquired soil nutrients (Mengel and Kirkby, 2001). The Eleti-eku on the contrary showed an efficient utilization of acquired soil nutrients by averagely obtaining soil nutrients for maximum performance. The lowest residual soil nutrients from the three varieties of jute mallow evaluated were observed in the control suggesting that there were not enough nutrients in the soil to support good crop performance. The fact that under the control, the OC for Eleti-eku was higher than the other varieties suggests that the variety has a more rooting system, which assisted in improving the variety's ability to mine nutrients from the soil. Consequently, more N and P were removed from the soil.

Conclusion

The application of AMF inoculum and Sokoto rock phosphate increased the growth and yield in jute mallow, and their combination further enhanced jute mallow performance. There was no appreciable difference in the performance of the varieties of jute mallow. However, the Eleti-eku variety of jute mallow responded better to soil amendments, with the highest growth performance observed with the application of AMF inoculation combined with rock phosphate. Nonetheless, the best response of Amugbadu and Oniyaya was through the application of rock phosphate and AMF+RP, respectively.

Furthermore, the rate of mycorrhizal root infection was highest in the Eleti-eku variety of jute mallow compared to the other varieties in the two croppings.

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Soil Quality Assessment in Organic and Conventional Systems of Citrus Orchards Management in Ibadan, Southwestern Nigeria

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Abstract

Soil quality in organic and conventional management systems of citrus orchards was evaluated and compared with a natural forest in the National Horticultural Research Institute (NIHORT) Idi-Ishin, Ibadan, Oyo State. A total of 108 soil samples were collected at regular intervals at a depth of 0 – 15 cm, 15 – 30 cm, and 30 – 60 cm in organically managed and conventionally managed citrus plantations for approximately 23 years with samples from the natural forest as check. Routine soil analyses were carried out in addition to microbial biomass carbon (MBC) and microbial count using standard procedures. The soil quality index was calculated using the method postulated by Bajracharya. The soil pH (6.8 – 6.9) of the organic citrus orchard was neutral, while the conventional citrus orchard was slightly acidic (pH 6.5). Soil organic carbon varied from 26.4 g/kg in the organic citrus orchard to 18.2 g/kg in the conventional citrus orchard, Total Nitrogen from 0.21 g/kg to 2.64 g/kg, Available Phosphorus from 2.2 mg/kg to 11.0 mg/kg. The soils of the organic citrus orchard were loamy sand to sandy loam while the conventional citrus orchard was sandy to loamy sand. The organically managed citrus orchard has MBC of 0.75 mg/kg bacterial count of 5.1 x 10^3 CFU, a fungi count of 1.6 x 10^3 CFU, which is significantly higher than the conventional citrus orchard with MBC of 0.68 mg/kg bacterial count of 4.7 x 10^3 CFU, and fungi count of 1.2 x 10^3 CFU. The soil quality ranking of the organic citrus orchard at depth 0 – 15cm, 15 – 30 cm, and 30 – 60 cm at 0.59, 0.59, and 0.70 were designated as fair and good respectively while the conventional orchard had 0.50, 0.50, and 0.61, designated as poor and fair. Higher biological activities in the organic management system influenced levels of organic matter, microbial contents, and greater microbial diversities. The higher soil quality sindex in the organic citrus orchard indicates that the organic management system has better soil quality and a higher potential for long-term sustainability.

Évaluation de la qualité du sol dans les systèmes biologiques et conventionnels de gestion des vergers d'agrumes à Ibadan, dans le sud-ouest du Nigeria

Résumé

La qualité du sol dans les systèmes de gestion biologique et conventionnelle des vergers d'agrumes a été évaluée et comparée à une forêt naturelle à l'Institut national de recherche horticole (NIHORT) Idi-Ishin, Ibadan, État d'Oyo. Au total,

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RÉSEAU DES CHERCHEURS EN AGRICULTURE BIOLOGIQUE EN AFRIQUE
شبكة الباحثين في الزراعة العضوية بإفريقيا

108 échantillons de sol ont été prélevés à intervalles réguliers à une profondeur de 0 à 15 cm, 15 à 30 cm et 30 à 60 cm dans des plantations d'agrumes gérées de manière biologique et conventionnelle pendant environ 23 ans avec des échantillons de la forêt naturelle comme contrôle. Des analyses de sol de routine ont été effectuées en plus du carbone de la biomasse microbienne (MBC) et du comptage microbien en utilisant des procédures standard. L'indice de qualité du sol a été calculé en utilisant la méthode postulée par Bajracharya. Le pH du sol (6,8 – 6,9) du verger d'agrumes biologique était neutre, tandis que le verger d'agrumes conventionnel était légèrement acide (pH 6,5). Le carbone organique du sol variait de 26,4 g/kg dans le verger d'agrumes biologiques à 18,2 g/kg dans le verger d'agrumes conventionnel, l'azote total de 0,21 g/kg à 2,64 g/kg, le phosphore disponible de 2,2 mg/kg à 11,0 mg/kg . Les sols du verger d'agrumes biologique étaient de sable limoneux à limon sableux tandis que le verger d'agrumes conventionnel était de sable limoneux à sable limoneux. Le verger d'agrumes géré de manière biologique a un MBC de 0,75 mg/kg de numération bactérienne de 5,1 x 103 UFC, un nombre de champignons de 1,6 x 103 UFC, ce qui est significativement plus élevé que le verger d'agrumes conventionnel avec un MBC de 0,68 mg/kg de numération bactérienne de 4,7 x 103 UFC et un nombre de champignons de 1,2 x 103 UFC. Le classement de la qualité du sol du verger d'agrumes biologiques à une profondeur de 0 à 15 cm, de 15 à 30 cm et de 30 à 60 cm à 0,59, 0,59 et 0,70 a été désigné comme passable et bon respectivement, tandis que le verger conventionnel avait 0,50, 0,50 et 0,61. , désignée comme pauvre et juste. Des activités biologiques plus élevées dans le système de gestion biologique ont influencé les niveaux de matière biologique, le contenu microbien et une plus grande diversité microbienne. L'indice de qualité du sol plus élevé dans le verger d'agrumes biologiques indique que le système de gestion biologique a une meilleure qualité du sol et un potentiel plus élevé de durabilité à long terme.

Mots-clés:
Qualité du sol, systèmes de gestion, verger d'agrumes, carbone de la biomasse microbienne

Introduction

Soil quality is the capacity of soil to function as a vital living system to sustain biological productivity, promote environmental quality, and maintain plant and animal health (Richard *et al*., 2018). The soil is healthy if it has good physical, chemical, and biological properties to support its intended use and focus has been on this functional approach in the measurement of soil quality. The status of the world soil resources (FAO, 2015) showed that majority of soils are in poor or very poor conditions. Some of the worrisome conditions are high degree of erosion, and increased soil acidity with lack of soil nutrients constraining food production (Kopittke *et al*., 2019). This calls for a clear need to access the extent to which soil quality is affected by current human interventions (Soderstrom *et al*., 2014) in addition to detecting hotspots along supply chains as well as possible sustainable soil management options (Borghi *et al*., 2014). Quantifying impacts on soil functions is challenging given the complexity of soil processes, spatial and temporary variability of soil properties (Adhikari *et al*., 2014). Therefore, accounting for this variability determines the adequacy of the soil quality model to represent local conditions.

Soil management systems are various methods employed by humans most especially farmers to sustain or improve soil quality, enhance crop growth, and water usage, and protect the environment (Barrios *et al*., 2011). Management systems involve fertilizer applications, irrigation, mulching, tillage, organic and conventional farming among a few others. The soil quality can be either degraded or improved based on the management systems practiced. Conventional management system is a common practice carried out in agricultural land which can degrade the soil structure, soil organic matter, soil biota, and reduce aggregate stability. It exposes the soil to the direct impact of rain that will lead to run-off and soil erosion. The organic management system on the other hand gives better soil protection as this system tends to have higher organic matter that favours the soil organisms, better soil aggregates, less run-off, and erosion. Besides, the soil will be subjected to less nutrient loss often caused by soil erosion thus sustaining quality of the soil and at the same time protecting surface water from pollution.

Citrus (*Citrus sinensis*) is a genus of flowering tree and shrub in the family Rutaceea. It is a small shallow-rooted evergreen shrub or tree about 6 – 13 m high with an enclosed conical top and mostly spiny branches. It is a premier fruit crop grown for fresh consumption and as raw material in tropical and sub-tropical regions (Adewale *et al*., 1996; NIHORT, 2008). The juice contains a high quantity of citric acid giving it a characteristic sharp flavor. It is a good source of vitamin C and flavonoids. Citrus is globally considered as one of the premier fruits both in terms of area and production. Sub-optimum production due to the prevalence of nutrient constraints is well established in citrus, as in other crops (Mattos *et al*., 2020).

It has been suggested by several authors that soil quality is needed for long-term sustainability of agronomic management systems (Moebius-Clune *et al*., 2016). As the demand for food production increases to meet the growing population needs, additional stresses will be placed on our soils and the consequences will be reflected in diminished soil quality thereby affecting the soil's continued ability to produce food (Gomiero *et al*., 2011). Instead of focusing on greater yields in production agriculture which will eventually exhaust soil nutrients, the goal should be management systems that have the capability to improve soil quality (Rodale institute, 2015). Soil quality can be indicated by various factors which are good soil tilt, sufficient depth, good water storage, and good drainage, sufficient supply but not an excess of nutrients, a small population of plant pathogens and insect pests, a large population of beneficial organisms, low weed pressure, free of chemicals and toxins that may harm the crop, resistance to degradation and resilience when unfavorable conditions occur (Barrios *et al*., 2011). The numerous benefits include better plant growth, quality yield, reduced risk of yield loss during the period of environmental stress, better field access during wet periods, reduced fuel cost by requiring less tillage, reduced input costs by decreasing losses, and improving use efficiency of fertilizers, pesticides, herbicides, and irrigation applications (Ishaq *et al*., 2015).

The National Horticultural Research Institute (NIHORT), the site where this study was carried out, has been well known for tree crops (Citrus *spp*) production. However, available literature showed that there is a paucity of information on soil quality data in the study area. This study was therefore, carried out to assess the soil quality of two orchards that were managed differently; one was organically managed and the other was managed conventionally. Both were compared with an undisturbed forest. It is believed that a closer look may reveal a possible threat to soil quality under the different management systems. It may also point out mitigation or corrective measures for long-term productivity and sustainability of an agricultural management system.

Materials and Methods

Study area

The experiment was conducted at the National Horticultural Research Institute (NIHORT), Idi- Ishin Ibadan, Oyo State, Nigeria located within latitude 07° 24.484′ N - 07° 24.410′ N and longitude 3° 50.672′ E - 03° 50.719′ E of the equator. The location has a mean annual rainfall of 1100 – 1400mm (NIMET, 2017). It has a minimum temperature of about 21° C and a maximum temperature of 30°C with relative humidity of over 70%. Ibadan has a humid climate and experiences a bimodal rainfall distribution pattern, having a total annual rain days of 200 – 250 days and 9 – 10 months of rainfall with peaks in June/July and September. The study was carried out on a pair of citrus orchards, one is managed organically and the other is conventionally managed for approximately 23 years. Organic fertilizers and materials are applied in the organic system at 5 years interval, and weed is controlled by slashing while urea is applied in the conventional system and weed is controlled with paraquat. A natural forest adjoining the fields were used as a natural check. The total size of the study area is about 7715 m^2. The map of the study area is shown in Figure 1.

Field study

The area was geo-referenced with the use of a GPS device used in locating reference points on the field. A rigid grid sampling method was used and laid at 14 m x 21 m apart. Thirty-six (36) points were sampled to a depth of 0 – 15 cm, 15 – 30 cm, 30 – 60 cm using the Auger sampling method. Sixteen (16) sampling points each in both orchards and six (3) sampling points in the natural forest; 108 samples in total were obtained using this method. Nine (9) fresh samples of 0 –15 cm were collected for microbial analysis. Three (3) samples in each of the orchards and three (3) samples from the natural forest.

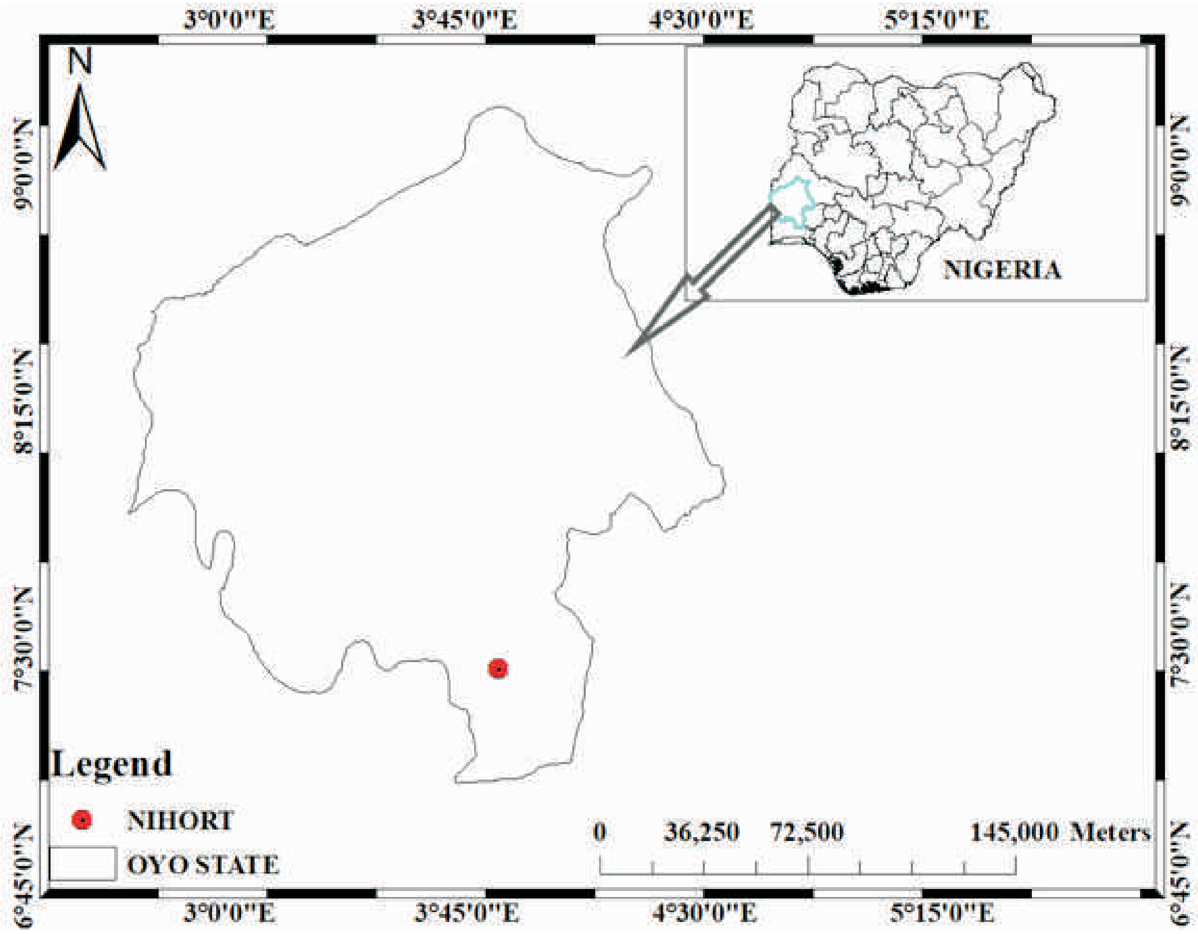

Figure1: Map of Oyo State showing the study location

Laboratory analyses

Particle size distribution was determined using the modified hydrometer method (Day, 1965), hydraulic conductivity was measured in undisturbed samples collected with cylindrical metal cores measuring 5.5cm in diameter using Darcy's law derived from in vertical column. Bulk density was determined from core samples after oven drying to constant weight at a temperature of 105°C. Soil pH was determined in water with a ratio of 1:1 using a glass electrode pH meter**.** Organic carbon was determined using the wet chromate oxidation method. Total nitrogen was determined using the mico-kjehdahl method (Jackson, 1962). Available phosphorus (P) was determined using Mehlich III (Mehlich, 1984) extraction, and the concentration assayed in the ascorbic acid (blue colour) on a spectrophotometer. Exchangeable acidity was determined using the method of Mclean (1965). Exchangeable cations (K, Na, Ca and Mg) were leached with neutral normal acetic acid while extractable micronutrients (Cu, Zn, Fe and Mn) were extracted with dilute HCl solution. The concentrations of K and Na were determined with Flame photometer while the other cations and micronutrients were done using Atomic absorption Spectrometer (AAS). The Effective Cation Exchange Capacity (ECEC) was calculated as the sum of exchangeable cations and the exchangeable acidity and base saturation was computed.

The microbial biomass Carbon (MBC) was determined by fumigation extraction method. MBC was calculated from the relationship between the amount of organic C extracted from the fumigated and non-fumigated soils (Vance *et al.*, 1987). Microbial counts were obtained from fresh soil samples and were analysed for colonies counts as colony forming units (CFU of bacteria and fungi using the pour plate method described by Oskay *et al.*, (2004).

Soil quality index

Soil quality index values proposed by Bajracharya *et al*. (2007) were calculated by using the following equation:

$$SQI = [(a*R_{STC}) + (b*R_{pH)+}(c*R_{OC}) + (d*R_{NPK})]$$

Where RSTC, RpH, ROC, RN, RP, RK are assigned ranking values for soil textural class, soil pH, soil organic carbon, nitrogen, phosphorus and potassium. While a = 0.2, b = 0.1, c = 0.4, and d = 0.3 are weighted values corresponding to each parameters.

The scoring method used to interpret this SQI was developed by Nepal Agricultural Research (NARC) and highlighted in Table 1. The level of soil pH and soil fertility was determined using a soil pH and fertility interpretation chart developed by NARC as shown in Tables 2 and 3.

Table 1: Soil quality index on assigned range values suggested by NARC for commonly used soil parameters

Parameters	Ranking Values				
	0.2	0.4	0.6	0.8	1
Soil textural class	C, S	SiC, Cl, Sc	Si, L, S	L, SiL, Sl	SiCl, Sc
Soil pH	< 4	4.1-4.9	5-5.9	6-6.4	6.5-7.5
SOM (%)	< 0.5	0.6-1	1.1-2	2.1-4	> 4
Fertility (NPK)	Low	Mod. Low	Moderate	Mod. High	High/Best
SQI	V. Poor	Poor	Fair	Good	Best

Legend: C-clay, S-sand, CL- Clay loam, SC- sandy clay, SiC - silty clay, Si- silt, LS – loamy sand, SiL – silty loam, SL – sandy loam, SiCL – silty clay laom, SCL – sandy clay loam, SQI – soil quality index, SOM- Soil organic matter.

Table 2: Soil pH interpretation (NARC)

pH range	Interpretation
< 4.5	Strongly acidic
4.5- 5.5	Moderately acidic
5.5- 6.5	Weakly acidic
6.5- 7.5	Nearly acidic
>7.5	Alkaline

Table 3: Interpretation of soil fertility (NARC)

OM (%) Range level	TN (%) Range level	AP (kg/ha) Range level	K (kg/ha) Range level
< 2.5 low	< 0.1 low	< 31 low	110 low
2.5- 5.0 moderate	0.1- 0.2 medium	31- 35 moderate	110- 280 medium
>5.0 high	>0.2 high	>55 high	>280 high

OM- Organic matter, TN- Total Nitrogen, AP- Available Phosphorus, K- Potassium.

Statistical analysis

Data on microbial biomass carbon were subjected to analysis of variance at p≤0.05 using Genstat statistical package (4th edition). Data on soil physical and chemical properties were also correlated.

Results

Physical, chemical, and biochemical soil quality indicators

The organically managed system

The mean value of the soil quality indicators varied in the management system. The soil pH was nearly neutral ranging from 6.8 to 6.9 (Table 4). The organic carbon was moderate in 0-15cm, low in 15-30 cm and 30-60 cm depth, respectively. The value ranged from 1.56% – 2.64 %. The total nitrogen was low and the value ranged from 0.02% – 0.03 %. The available phosphorus was low with the value ranging from 0.49 kg/ha to 4.88 kg/ha. The exchangeable potassium was as well low. There were four textural classes; sand, loamy sand, sandy loam, and sandy clay loam. The bulk density, total porosity, and hydraulic conductivity mean values were 1.43 g/cm3, 47.0 %, and 10.0 cm/hr (Table 5). The fungi and bacteria count mean values were 12 CFU/10^3 and 51 CFU/ 10^3 respectively (Table 6). The spore count showed that Mucor was prevalent, followed by Penicellium and Aspergillius Niger. The mean value of the microbial biomass carbon was 0.77 mg/kg.

Table 4: Means of selected chemical indicators of the sampling points of the study area

Sampling Points	Depth (cm)	pH (H20)	Org. C	Total N	Avail. P (mg/kg)	E.A	ECEC	Base Sat. (%)
			(g/kg)			(cmol/kg)		
Organic citrus orchard	0-15	6.9	26.4	0.21	2.2	0.2	5.32	95.80
	15-30	6.9	17.7	0.34	0.7	0.2	5.27	94.83
	30-60	6.9	15.6	0.26	0.2	0.2	5.90	95.38
Conventional citrus orchard	0-15	6.8	18.7	2.64	11.0	0.2	5.97	95.32
	15-30	6.7	9.4	2.91	10.4	0.4	5.10	91.01
	30-60	6.5	8.2	1.94	2.8	0.6	4.13	85.89
Natural Forest	0-15	6.9	38.3	2.91	7.8	4.2	7.80	98.10
	15-30	7.1	25.6	1.37	6.5	1.4	6.50	95.95
	30-60	7.1	24.5	0.21	7.26	1.0	7.26	97.55

EA- Exchangeable Acidity, ECEC - Exchangeable cation exchange capacity

The conventionally managed system

The mean value of the soil quality indicators varied in the management system. The pH was nearly neutral with value which ranges from 6.5 -6.7 (Table 4). The organic carbon was low with value 0.82- 1.87%, the total nitrogen was moderate across the depths and the value ranged from 0.19- 0.26 kg/ha. The exchangeable potassium was low across the various depths. The textural classes were sand and loamy sand. The bulk density, total porosity, and hydraulic conductivity mean values were 1.41 g/cm3, 46.0 %, and 12.0 cm/hr. (Table 5). The fungi and bacteria count mean values were 16 CFU/10^3 and 47 CFU/ 10^3 respectively (Table 6). The spore count showed that Aspergillious Niger and Rhizopus were prevalent, followed by Penicellium. The mean value of the microbial biomass carbon was 0.75 mg/kg.

The Natural forest (Check)

The mean value of the soil quality indicators varied in the undisturbed forest. The soil pH was nearly neutral which ranged from 6.9 to 7.1 (Table 4). The organic carbon was moderate in both 0-15cm and 15-30 cm and low in 30-60 cm depth. The value ranged from 2.44% – 3.83 %. The available phosphorus was low and the value ranged from 1.15 kg/ha to 9.43 kg/ha. The exchangeable potassium was as well low. The textural classes were; sandy loam, loamy sand and sandy clay loam (Table 5). The bulk density, total porosity, and hydraulic conductivity mean values were 1.48 g/cm3, 44 %, and 3.56 cm/hr. The fungi and bacteria count mean value were 12 CFU/10^3 and 45 CFU/ 10^3 respectively (Table 6). The spore count equally showed that Rhizopus spp and Mucos were prevalent followed by Aspergilliuos spp. The mean value of the microbial biomass carbon was 0.53 mg/kg.

Table 5: Means of selected physical indicators of the sampling points of the study area

Sampling points	Depth	Coarse sand	Fine sand	Total sand	Silt	Clay	Hydraulic Conductivity	Bulk Density	Gravel	Total Porosity
	(cm)	g/kg					(cm/hr)	(g/cm^3)	%	
Organic citrus orchard	0-15	723.2	126.6	849.8	99.0	50.5	10.57	1.43	13.23	46.1
	15-30	699.6	157.1	856.7	101.5	56.7	9.96	1.43	23.24	45.9
	30-60	703.5	116.5	819.0	107.5	69.8	9.0	1.44	30.43	45.6
Conventional citrus orchard	0-15	737.2	108.7	845.9	129.0	27.0	12.35	1.41	5.14	46.8
	15-30	685.0	189.0	874.0	101.5	25.7	13.04	1.40	9.22	46.9
	30-60	731.8	145.8	877.6	92.4	29.5	12.84	1.40	13.12	46.8
Natural Forest	0-15	631.6	105.8	737.4	134.0	136.0	4.64	1.48	31.45	44.1
	15-30	604.2	123.5	727.7	115.6	15.6.	4.71	1.48	47.2	44.2
	30-60	566.6	77.3	643.9	116.5	239.5	1.32	1.51	40.62	43.0

Table 6: Microbial biomass carbon and microbial count of the soils of the study area

Land use types	Microbial Biomass Carbon (mg/kg)	Bacterial Count (CFU x 10^3)	Fungi Count (CFU x 10^3)
Organic citrus orchard	0.77	5.1	1.6
Conventional citrus orchard	0.68	4.7	1.2
Natural Forest	0.53	4.5	1.2
LSD (0.05)	0.037	NS	NS

Soil quality index rating

Soil quality rating of the organically managed system (Table 7) varied with depths. The soil organic carbon was moderate at 0 – 15 cm depth, low at 15 – 30 cm and 30 – 60 cm depth respectively. Nitrogen level was moderately low in 0 – 15 cm and poor in both 15 – 30 cm and 30 – 60 cm depth. The soil quality index rating of 0 – 15 cm depth was good while 15 – 30 cm and 30 – 60-cm depths were fair respectively. The inorganically managed system (Table 7) had a soil quality rating of fair, in both 0 – 15 cm and 15 – 30 cm depths and poor in 30 – 60 cm depth. The soil organic carbon was low across the three depths, the fertility level was moderate in 0 -15 cm and moderately low in 15 – 30 cm and 30 – 60 cm. The soil quality rating of undisturbed forest (Table 4.11) was good across the three depths. The soil organic carbon was moderate across the three depths, the fertility level was fair in both 0 – 15 cm and 15 – 30 cm while low in 30 – 60 cm depth.

Table 7: Soil quality rating of the soils of the study area

Sampling point	Depth (cm)	T.S	Silt	clay	T. class	pH (H_2O)	OC	TN	AP (mg/kg)	K (kg/ha)	SQI	Rating
			(g/kg)				(%)					
Organic citrus orchard	0-15	84.98	9.90	5.05	S, LS, SL	6.9	2.64	0.21	2.18	150.57	0.70	GOOD
	15-30	85.67	10.15	5.67	S, LS, SL	6.9	1.77	0.34	0.73	96.80	0.59	FAIR
	30-60	92.00	10.75	6.98	S, LS, SL	6.9	1.56	0.26	0.22	101.08	0.59	FAIR
Conventional citrus orchard	0-15	84.59	12.90	2.70	S, LS	6.7	1.87	2.64	11.02	142.97	0.61	FAIR
	15-30	87.40	10.15	2.57	S, LS	6.6	0.93	2.91	10.40	76.44	0.50	POOR
	30-60	87.76	9.24	2.95	S, LS	6.5	0.82	1.94	2.86	70.98	0.50	POOR
Natural Forest	0-15	73.75	13.40	13.60	SL	6.9	3.83	2.91	4.21	245.38	0.80	GOOD
	15-30	72.75	11.56	15.6	SCL	7.1	2.56	1.31	1.35	149.52	0.80	GOOD
	30-60	66.9	11.65	23.95	SCL	7.1	2.44	0.21	0.96	166.14	0.70	GOOD

OC- organic carbon, TN- total nitrogen, AP- available phosphorus, K- potassium, SQI- soil quality index, T- textural, S- sand, LS- loamy sand, SL- sandy loam, SCL- sandy clay loam, TS- total sand

Discussion

Maintenance of soil quality is a key component of agriculture sustainability and there is an increase in the use of soil microbial parameters as sensitive indicators. The biological component of the soil is mainly represented by microorganisms, which play an important role in soil formation and soil fertility (Brumme *et al.*, 2009). Therefore, measuring microbial biomass is a valuable tool for understanding and predicting the long-term effects of changes in land use and associated soil conditions (Gao *et al.*, 2014).The results of microbial biomass analysis showed that the organically managed system has a mean microbial biomass carbon (MBC) of 0.75 %, fungi and bacteria count of 16 CFU/10^3 and 51 CFU/10^3. This is in agreement with the finding of Kara and Bolat (2008) that relatively dense growth of plants, *vis-à-vis* greater accumulation of litter and fine roots favour the growth of microbial populations and accumulation of carbon in the microbial biomass. The organic carbon was moderate at 0-15cm, low in 15-30 cm and 30-60 cm depth respectively. The value ranged from 1.56% – 2.64 %. Increases in soil organic matter content depend on the amount and types of organic materials applied, and the duration of application (Spiegel *et al.*, 2015). Higher organic input under the organic farming system leads to a more vibrant soil life, which in turn creates a more stable soil structure (Tsiafouli *et al.*, 2014). The soil pH was nearly neutral ranging from 6.8 to 6.9 which indicate favourable condition for microbial activities (Acosta Martinez and Tabatabai, 2000). Generally, soil pH depends on the soil type and its buffering capacity, and the type of organic fertilizer or soil amendment applied (Bunemann *et al.*, 2018). The total nitrogen was low with the value ranging from 0.02 – 0.03 % which might be due to high nitrogen mineralization. The available phosphorus was low with the value ranging from 0.49 kg/ha to 4.88 kg/ha which suggests a lack of phosphate rock. The exchangeable potassium was as well low.

Understanding physical soil properties is a key issue since soil properties vary spatially within a field because of geological and pedological soil-forming factors (Orimoloye *et al*, 2018). There were four textural classes; sand, loamy sand, sandy loam, and sandy clay loam. The bulk density, total porosity, and hydraulic conductivity mean values were 1.43 g/cm3, 47 %, and 10 cm/hr. The bulk density value suggests good root penetration while the value of porosity and hydraulic conductivity suggests poor water-holding capacity and nutrients retention.

Soil quality (SQ) rating refers to current conditions of a soil including the medium-term soil hydrological, thermal, geological, and terrain conditions and the human impact (soil forming factors). The soil quality was calculated using the soil quality index proposed by Bajracharya *et al*. (2007). The index comprises soil texture, pH, organic carbon, nitrogen, phosphorus, and potassium. The organic management system was rated best to fair with corresponding depths of 0 – 15 cm, 15 – 30 cm, and 30 – 60 cm.

The conventional management system has a mean microbial biomass carbon (MBC) of 0.68 mg/kg, fungi and bacteria count of 12 CFU/10^3 and 47 CFU/10^3. This is in agreement with the finding of Kara and Bolat (2008) that relatively dense growth of plants, *vis-à-vis* greater accumulation of litter and fine roots favour the growth of microbial populations and accumulation of Carbon in the microbial biomass. The pH was nearly neutral with the value ranging from 6.5 to 6.7, similar to that of the organic management system. The organic carbon was low with a value of 0.82% - 1.87 %. This is in agreement with the finding of Spiegel *et al.,* (2015) that the increase in soil organic matter content depends on the amount and types of organic materials applied, and the duration of application. The total nitrogen was moderate across the depths with the values ranging from 0.19 kg/ha - 0.26 kg/ha which suggests moderate nitrogen mineralization. The available phosphorus was moderate which suggests the presence of phosphate rock. The exchangeable potassium was low across the various depths which might be due to leaching. The textural classes were sand and loamy sand. The bulk density, total porosity, and hydraulic conductivity mean values were 1.41 g/cm3, 46 %, and 12 cm/hr. The bulk density value suggests good root penetration while the value of porosity and hydraulic conductivity suggests poor water holding-capacity and nutrients retention. The conventional management system was rated fair to poor with corresponding depths of 0 – 15 cm, 15 – 30 cm and 30 – 60 cm.

The undisturbed forest has a microbial biomass carbon of 0.53 %, fungi and bacteria count of 12 CFU/10^3 and 45 CFU/10^3. The soil pH was nearly neutral ranging from 6.9 to 7.1. The organic carbon was moderate in both 0-15cm and 15-30 cm and low in 30-60 cm depth. The value ranged from 2.44 – 3.83 %. The available phosphorus was low with the value ranging from 1.15 kg/ha to 9.43 kg/ha. The exchangeable potassium was moderate. The textural classes were; sandy loam, loamy sand and sandy clay loam. The bulk density, total porosity, and hydraulic conductivity mean values were 1.48 g/cm3, 44 %, and 3.56 cm/hr. The bulk density value suggests good root penetration while the values of porosity and hydraulic conductivity suggest good water-holding capacity and nutrients retention. The soil quality was rated well across the various depths.

Conclusion

The petro-plinthites observed at the conventional management system might have been caused as a result of repeated plowing and could have been aggravated by reactions with chemical inputs in the conventional system. Soil quality is better maintained in the organic citrus management system than in the conventional system being closer to the natural forest in most of the quality parameters considered. The microbial biomass analysis also showed that the organically-managed system favoured the growth of microbial populations and the accumulation of carbon in the microbial biomass. This is an indication that the organic management system had higher levels of organic matter, microbial contents, and greater microbial diversities. The organic management system could be recommended to farmers on this basis since it promises to be sustainable. The organic citrus system can be improved through the addition and frequent application of quality organic manure (poultry manure, pig slurry) to hold soil particles together, supply nutrients, and increase the CEC of the soil. Planting of cover crops will also supplement the nitrogen level of the soil.

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pp.83-88

The Effects of Different Concentrations of Aqueous Garlic (*Allium sativum*) Extract on Root-Knot Nematode (*Meloidogne specie*) Infected Celosia

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Abstract

The reliance, indiscriminate and overuse of synthetic pesticides in most developing countries is now widely discouraged. This is because of their devastating impacts on the environment, economic and health of the population. The study was therefore carried out to assess the nematicidal potentials of different concentrations of aqueous garlic extracts on root-knot nematode eggs and on nematode infected Celosia plants. The experiment consisted of five treatments replicated ten times and laid out in a completely randomized design. The treatments were: uninoculated control plants, inoculated untreated plants (7,000 nematode eggs), inoculated plants treated with 25% aqueous garlic extract, inoculated plants with 50% aqueous extract and inoculated plants treated with 75% aqueous garlic extract. Data were collected on growth and yield parameters during active growth, and galling indices was also determined for the five treatments and data were analysed using ANOVA. Percentage hatchability test was carried out on nematode eggs treated with different concentrations in a laboratory assay. Results from this study showed that 75% concentration of the extract had the least number of *Meloidogyne* egg hatch from day 1-6. The highest number of egg hatch was observed in the control solution. At the end of day 6, 88%, 53%, 29% and 23% hatching was observed for control, 25% garlic extract, 50% garlic extract and 75% aqueous garlic extract respectively. The uninoculated plant had the highest number of leaves and stem heights indicating that the root-knot nematode reduced the growth parameters in the infected *C. argentia*. The galling indices was highest for the untreated Celosia plants and decreased as the concentration of aqueous garlic extract increased.

Effets de Différentes Concentrations D'extrait Aqueux D'ail (*Allium sativum*) Sur des Céloses Infectuées par le Nématode des Racines (*Espèce Meloidogne*)

Résumé

Dans la plupart des pays en développement, la dépendance, et la surutilisation des pesticides synthétiques sont maintenant largement découragés. Ceci en raison de leurs impacts dévastateurs sur l'environnement, l'économie et la santé de la population. L'étude a donc été menée pour évaluer le potentiel nématicide de différentes concentrations d'extraits aqueux d'ail sur des œufs de nématodes à galles et sur des plantes Celosia infectées par des nématodes. L'expérience consistait en cinq traitements répétés dix fois et disposés selon un plan complètement randomisé. Les traitements étaient les suivants : plantes témoins non inoculées, plantes inoculées non traitées (7000 œufs de nématodes), plantes inoculées traitées avec un extrait aqueux d'ail à 25%, plantes inoculées avec un extrait aqueux à 50% et plantes inoculées traitées avec un extrait aqueux d'ail à 75%. Des données ont été collectées sur les paramètres de croissance et de rendement pendant la croissance active, et les indices de galle ont également été déterminés pour les cinq traitements et les données ont été analysées en utilisant ANOVA. Un test d'éclosion en pourcentage a été effectué sur les œufs de nématodes traités avec différentes concentrations dans un essai de laboratoire. Les résultats de cette étude ont montré que la concentration de 75% de l'extrait avait le plus petit nombre d'éclosion d'œufs de Meloidogyne du jour 1 à 6. Le nombre le plus élevé d'éclosion d'œufs a été observé dans la solution sous controle. A la fin du jour 6, 88%, 53%, 29% et 23% d'éclosion ont été observés pour le contrôle, l'extrait d'ail à 25%, l'extrait d'ail à 50% et l'extrait d'ail aqueux à 75% respectivement. La plante non inoculée avait le plus grand nombre de feuilles et la plus grande hauteur de tige, ce qui indique que le nématode à galles a réduit les paramètres de croissance de la C. argentia infectée. Les indices de galles étaient les plus élevés pour les plantes Celosia non traitées et diminuaient avec l'augmentation de la concentration de l'extrait aqueux d'ail.

Mots-clés:
Aqueux,
Non inoculé,
Meloidogyne

Introduction

The use of synthetic agro-chemicals in developing countries to reduce pests and diseases present serious environmental problems to growers especially the peasant farmers who depend on agriculture for sustenance and livelihood. Most often, the response of increasing demand for food has always been in form of increased use of agro-chemicals. These chemical pesticides are often poorly handled resulting in the contamination of the environment.

Globally, there is increasing demand in favour of natural pesticides among consumers and farmers. Farmers may also find this approach acceptable due to ease of accessibility in their local environment and aligned with their normal way of life (Peluola and Fadina, 2014).

Nature herself has offered us a profusion of plants for use in natural crop protection for a cleaner and safer environment (Fadina and Adesiyan, 1997). One of such plants is *Allium sativum* (garlic). This plant is widely known in Nigeria and it is believed to be antimicrobial and anti-filarial. In addition to the use of garlic as a spice, traditionally, garlic has been used in the treatment of worms and dysentery in children and adults (Ngeze, 2001).

In Nigeria, one crucial and important factor which affects vegetable production are pests and diseases. Nematodes are the most important disease-causing agents in the tropics. Attack from nematodes also pre-dispose plants vulnerable to infections by secondary invaders such as bacteria, fungi and viruses. The different methods for the control of *Meloidogyne* species on vegetable include biological control, use of resistant varieties, improved cultural practices and the use of chemical pesticides (Nematicides).

Chemical control method have been found to be very effective in the control of root-knot nematodes. The most commonly used group pesticides include the organochlorines and the organophosphates. The organochlorines are highly persistent in the environment and thus not environmentally safe, of which of a couple of them have been banned (Okafor and Fadina, 2013).

Most vegetables are often eaten in their fresh state or half-cooked and the chemical pesticides generally persist on the plants; it is therefore necessary for an alternative means of protecting vegetables so as to prevent the consumers being poisoned from pesticide residues.

The naturally occurring pesticides which are plant derivatives have assumed importance because they are bio-degradable, selective in action, non-toxic to mammals and generally less persistent and readily available. One of such plants is *Allium sativa* (garlic). The major objective of this study was to examine the nematicidal effects of *A. sativum* on eggs and adults of the root-knot nematode *Meloidogyne* species.

Materials and Methods

Preparation of inoculum:
Galled roots of *Celosia argentia* were obtained from an infested soil. The rooted galls were taken to the Bamidele Fawole Nematology Laboratory of the Department of Crop Protection and Environmental Biology in an air-tight, well labelled polythene bags to avoid drying or desiccation.

The method of Hussey and Baker (1973), was used for the extraction of *Meloidogyne* species. The galled roots were washed in running tap water and chopped into smaller pieces of about 1-2cm length and transferred into a conical flask, after this, 0.35% of sodium hypochlorite (NaOCl) was added to the nematode solution and shaken for 5 minutes, and then rinsed over two 45µm mesh sieves to collect large plant debris. The filtrate was then passed through 25 µm mesh sieve to collect the eggs. Water was then added continuously to the sieve containing the eggs in order to rinse all traces of NaOCl. The resultant solution was then diluted with distilled water to a 100ml mark in a beaker; nematode egg population was estimated by counting four samples of 2ml each from the nematode solution using a Doncaster counting dish and tally counter under a stereo microscope.

Preparation of garlic (*Allium sativum*) extract:
Fresh garlic bulbs were purchased from an open market in Ibadan, Oyo State, Nigeria. The garlic lobes were washed and air-dried on the laboratory bench. Air-dried garlic (25g) were then ground into powder and blended in 100ml of water for four minutes using a blending machine. The suspension was transferred into a beaker and wrapped up with an aluminium foil and then steam-boiled at 60^0c for two hours for the extraction of the active compounds (Peluola and Fadina, 2014).

Hatchability test of Nematode eggs:
Percentage hatchability test was carried out after the extraction by taking 1ml (50 eggs) of the inoculum solution and different concentrations of treatment (0%, 25%, 50% and 75%) with six replicates each, then poured in a petri-dish for six days.

The petri-dishes were observed daily and number of egg-hatch was done using a Doncaster counting dish. And the percentage of hatched nematodes were calculated.

Planting of seeds and nematode inoculation:
Top soil was collected at a fallow bush in the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria.

The soil was steam-sterilized at 160^0c for four hours, allowed to cool and stored. Seeds of *Celosia argentia* were collected from National Institute for Horticultural Research and Training (NIHORT) Ibadan and planted in 7kg pot filled with soil and later thinned to one healthy stand per pot. The design was a randomised complete block design of five treatments and ten replicates.

Two weeks after planting, the Celosia plants were inoculated with 7,000 nematode eggs with the exception of the control uninoculated plants. These eggs were added to the soil at the base of each plant root with aid of a 5ml hypodermic syringe after properly homogenizing the inoculum in the beaker to uniformly expose the nematode eggs. A week after inoculation the various treatments were applied to the plants. The treatments are, the uninoculated Celosia plants, nematode-inoculated Celosia plants, nematode-inoculated Celosia plants treated with 25% aqueous garlic extract, nematode-inoculated Celosia plants treated with 50% aqueous garlic extract, and nematode-inoculated Celosia plants treated with 75% aqueous garlic extract.

Upon harvest, roots were washed with water and assessed for the root-knot nematode galls using the galling indices rating scheme of Coyne *et al* (2007) where 1 - indicates no galling, 2 - indicates slight galling damage, 3 - mild galling damage, 4 - indicates heavy galling and 5 – severe galling.

Data collecting:

Data were collected on yield and growth parameters (up to week 8 after planting) and subjected to analyses of variance (ANOVA) using GENSAT, means were separated using least significant difference at 5% level of probability.

Results

Effect of different concentrations of garlic extract on *Meloidogyne* egg hatch:

On day 1, the 0% concentration of aqueous garlic extract had a mean percentage of 10% *Meloidogyne* egg hatch while 25% concentration had a mean percentage of 8% egg hatch. The 50% garlic concentration had 5% while 75% concentration of garlic extract had 1% of *Meloidogyne* egg hatch. From day 3, the percentage egg hatch increased progressively to 80% in day 6. But there were no further hatch in any of the treated concentrations from day 3. There were no hatching reactivation for any of the eggs (Fig.1).

Effect of different concentrations of garlic extract on mean number of *Celosia argentea* leaves:

At 5 weeks after planting, the uninoculated control plants had significantly more leaves than other treatments. However, the inoculated untreated plants had the lowest number of leaves. There were significant difference in the number of leaves between all the treated plants (Table 1).

Effect of different concentrations of garlic extract on stem height of *Celosia*:

At 5 WAP, the unimoculated control plants had the tallest stems while the 25% garlic extract treated plants had the lowest height. These trends was observed till 8 WAP. There were no significant differences in stem height among all the other treated plants (Table 2).

Effect of different concentrations of garlic on shoot and root weights:

The uninoculated control plants had the highest shoot and root weights while the 50% garlic extract treated plants had the lowest fresh shoot and root weights. There were no significant differences between all the other four treatments (Table 3).

Also, the uninoculated control plants had the highest dry shoot and root weights while the 50% treated plants had the lowest dry shoot and root weights. All the other treatments were not significantly different from each other in their dry shoot and root weights. (Table 4)

Effect of different concentrations of garlic extract on galling indices:

The inoculated untreated plants had the highest galling indices of 2.8 which belong to the mild galling group, this is followed by the 25% garlic extract treated plants with a mean galling indices of 2.33 (slight galling group). This is closely followed by 50% garlic treatment of 2.1 and finally to treatment with 75% garlic extract with mean indices of 1.7 (slight galling).

The uninoculated control plants had a mean galling index of which there is no galling damage (Table 5).

Table 1: Effect of different concentrations on mean number of leaves

Treatment	Weeks After Planting (WAP)			
	5	6	7	8
(Uninoculated control)	53.60	74.50	77.90	82.70
(Inoculated control)	17.30	31.80	39.50	46.10
(25% aqueous garlic extract)	17.60	32.70	42.20	47.80
(50% aqueous garlic extract)	19.00	38.50	47.70	55.60
(75% aqueous garlic extract)	21.40	33.30	44.10	16.65
$LSD_{0.05}$	8.79	9.42	9.79	16.65

Table 2: Effect of various concentrations on fresh shoot weight, fresh root weight, dry shoot weight and dry root weight

Treatment	**Fresh Shoot Weight (g)**	**Fresh Root Weight (g)**	**Dry Shoot Weight (g)**	**Dry Root Weight (g)**
(Uninoculated control)	82.39	13.61	15.95	2.57
(Inoculated control)	46.44	9.81	7.87	1.74
(25% aqueous garlic extract)	48.33	9.56	9.07	2.10
(50% aqueous garlic extract)	45.45	8.72	7.42	1.65
(75% aqueous garlic extract)	49.65	8.78	8.96	1.56
$LSD_{0.05}$	19.25	3.88	3.80	0.97

Discussion

Results from this study show that aqueous garlic extract of different concentrations (25%, 50%, and 70%) were effective in the control of root-knot nematode (*Meloidogyne*) disease of *Celosia argentea* due to the inhibitory effects on the growth and development of root-knot nematode on the crop and its effect on the egg hatchability Slusarenko *et al* (2008) described the constituents of garlic tissues as volatile antimicrobial substance allicin (diallythiosulphate) and the substance allin (S-ally) I-L-Cysteine sulphoxid which mixes the enzymes allin-lyase. Allicin also undergoes thiol-disulphide exchange reactions with free theoil groups in proteins. This mode of action is suggested as the basis for antimicrobial activities. In their studies, garlic juice was effective against some ranges of bacteria, fungi and oomycetes (Shisararenko, *et al*, 2008).

This study however shows that garlic extract at 75% concentration prove the most effective in the inhibition of egg hatch. Also, results from this study showed that the 75% concentration reduced the amount of galls (galling index) to 1.7 Okafor and Fadina (2013) reported the inhibitory effect of neem extracts on root-knot nematode on *Celosia* plant. They concluded that the inhibitory effect might be due to chemicals present in extract that possesses ovicidal and larvicidal properties. In this study, it was also observed that there were marked reduction in growth in the untreated inoculated plants, Odeyemi and Afolami (2008) reported stunted growth and root galling as main symptoms infection on host crop. *C. argentia* treated garlic extract proved to be effective in the production of more leaves in respect to plants treated with 25% and 75% of garlic extracts.

Therefore treatment of *Celosia* plants with 50% aqueous garlic extract are recommended for vegetable growers as it increased the yield and leaf number of *C. argentea*. These findings are therefore important in the control of root-knot nematode disease of vegetables without the use of any synthetic pesticides.

In view of the likelihood of occurrence of environmental pollution; this is because it has been observed that intensive vegetable production are always accompanied with frequent spraying of synthetic pesticides to improve the quality, thereby increasing profit (Okafor and Fadina (2003). However, sustainable agriculture is not just all about profit earned by farmers only, but it must also provide the consumers with safe food and minimize the adverse effects and impacts on the environment, farmers and consumers (Deang, 1991). The use of botanicals will go a long way in increasing farmers output without compromising their safety and that of the environment.

The FAO code on pesticides and the prior informed consent protocols should be adopted by the people and the government of the federation especially in the developing countries such as Nigeria. With the development of new classes of pesticides from natural plant to replace synthetics, dangerous and expensive chemicals used at present, the future of agriculture and vegetable production is bright (Adegbite and Adesuyan 2005). The cooperation of nematologists, plant breeders, chemists, toxicologists and other fields of agriculture is however important in achieving maximum progress in the control of nematodes on crops.

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pp.89-96

Productivity of Hot Pepper (*Capsicum frutescens* L.) Landraces as Affected by Organic Fertilizer in the Southern Guinea Savanna of Nigeria

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Abstract

Pot and field experiments were designed to study the effect of organic fertilizer on the growth and yield of hot pepper landraces. The treatment consisted of factorial combination of organic fertilizer levels (0, 1.5 and 3.0 t ha^{-1}) and hot pepper landraces (*Dan Zaria*, *Dan Sokoto* and *Mgbakpa*) arranged in a completely randomized design (CRD) in four replications in the screen house, and randomized complete block design (RCBD), replicated three times in the field. Application of organic fertilizer significantly ($P \leq 0.05$) affected plant height, number of leaves, fruit length and diameter, number of fruits per plant and fruit yield. The application of organic fertilizer at 1.5 t ha^{-1} to hot pepper significantly ($P \leq 0.05$) increased the plant height and number of leaves, fruits per plant, longer and bigger fruits, and higher fruit yield in the screen house and field conditions. The landrace *Mgbakpa* produced significantly ($P \leq 0.05$) taller plants, more leaves and fruits compared to the other landraces, in both conditions, except for plant height and number of leaves at 6 weeks after transplanting (WAT) in the screen house and plant height at 12 WAT in the field. Planting of *Dan Sokoto* and *Dan Zaria* landraces produced significantly ($P \leq 0.05$) longer and bigger fruits and maximum fruit yields. Based on the result of this study, farmers can obtain a better fruit yield of hot pepper by using *Dan Sokoto* and *Dan Zaria* with the application of 1.5 t ha^{-1} organic fertilizer.

Introduction

Pepper (*Capsicum* spp) is an economic important crop grown extensively by farmers under various environmental and climatic conditions for its fruit. Globally, it is cultivated on over 1.5 million hectares throughout the tropical, subtropical and temperate regions (Olatunji and Afolayan, 2018). Major pepper producing countries are Vietnam, China, Sri Lanka, India, Pakistan, India, Korea, Indonesia, Cambodia and Thailand in Asia, Ethiopia, Nigeria, Ghana, Tunisia and Egypt in Africa, Mexico and the United States in North and Central America, Spain, Bulgaria, Romania, Italy and Hungary in Europe, and Peru, Argentina and Brazil in South America (Olatunji and Afolayan, 2018, Assefa *et al*. 2020).

The genus *Capsicum* is made up of several wild species with only five species being commonly cultivated; such as C.*annum* L *frutescen* L., C. *chinense* (L.) Jacq., C.*baccatum* L., and C. *pubescents* L. (Getahum and

Habte, 2017). The crop is widely cultivated for its fruits, which are considered to be vegetables. According to Mebratu *et al*. (2014), hot pepper has the potential to improve the incomes and livelihoods of smallholder farmers and as well diversify and increase the agricultural export exchange earning of a country. Dennis and Kentus (2018) reported that there a high demand of pepper grown in Nigeria because of its pungency and good flavour attributes. This suggests that investing in pepper production is one means of curbing unemployment, income generation and sourcing of foreign exchange for the country (Dennis and Kentus, 2018).

In Nigeria, hot pepper (*Capsicum frutescens* L.) is third among the cultivated vegetable crops consumed in various forms, such as fresh, dried or processed products as vegetables, spices or condiments (Dennis and Kentus, 2018). It is an indispensable part of the daily diet of most millions of Nigerians (Monisola *et al.,* 2020). The smallholder farmers are known to produce the largest proportion of hot pepper in the country. In spite of its importance, hot pepper production for the green and dry pods has remained low.

The decline in hot pepper production has been attributed to shortage of improved varieties and lack of pure seed supply to farmers, poor quality of fruits, disease infestation, restriction of production to a single farming season, pervasive poverty, and low income among the smallholder farmers (Getahun and Habtie, 2017; Olatunji and Afolayan, 2018). Also, seeds used by the farmers are usually from previous harvests or purchased from the local markets, which are often mixed with other varieties and impurities containing pathogens (Getahum and Habtie, 2017). The other constraints include use of unimproved traditional horticultural practices, such as lack of knowledge in applying the optimum nutrients application and inadequate availability of disease and insect pests tolerant pepper varieties (Getahum and Habtie, 2017; and Assefa *et al*., 2020). Most soils in Nigeria lack the necessary macro and micro nutrients required to sustain crop production. Current statistics suggest an increase awareness in the use of fertilizer especially N, P and K (Mohammed *et al.* 2020). Yet the fertilizer use on hectare basis has remained low when compared with world average per hectare (Mohammed *et al.* 2020). This in turn has result in low productivity of crops, including hot pepper in Nigeria compared to other countries.

One potential approach to alleviate the major existing production constraints of hot pepper production, is to select the best adaptable crop varieties with high yield, quality, and resistance to biotic and abiotic stresses (Getahum and Habtie, 2017). Consequently, in this study, some common and available hot pepper landraces used by the smallholder farmers were selected and evaluated. Reason is that farmers mostly grow local selections because of the shortage of improved varieties. The use of organic fertilizer has been reported to be essential for the rapid growth with superior quality to all species of crops, because they have the nutrients necessary for better crop development and enhance soil fertility (Zayed *et al*., 2013). These fertilizers are also a source of substrate for soil microorganisms, which can increase the soil microbial activity by increasing organic material decomposition, release of nutrients for plant uptake and improve the soil physical properties (Zayed *et al*., 2013).

Research information on performance of hot pepper landraces with organic fertilizer source are scarce in this agroecology of Nigeria. Therefore, the objective of this study was to determine the optimum rate of organic fertilizer application on growth and yield of some hot pepper landraces.

Materials and Methods

The experiment was conducted during the dry season of 2019/2020 in the screen house of the Department of Crop Production, Federal University of Technology Gidan Kwano Campus Minna, and at Farmers Irrigation Field in Minna, Niger State, Nigeria. Minna is located in the Southern Guinea Savanna zone of Nigeria. The trial was conducted in the screen house and open field simultaneously; therefore, the experiment was conducted in the dry season from October, 2019 to March 2020. A 3 x 3 factorial experiment was laid out in Completely Randomized Design (CRD) with 9 treatments in four replications in the screen house and laid out in Randomized Complete Block Design (RCBD) with 9 treatments in three replications in the field. The two factors involved in the trial included, three (3) organic fertilizer rates (0, 1.5 and 3.0 kg ha^{-1}) and three pepper landraces (*Dan Zaria, Dan Sokoto* and *Mgbakpa*).

In the field, plants were spaced at 30 cm within and 75 cm between rows. The gross plot size was 3 m x 3 m (9 m^2) and a net plot size of 1.5 m x 3 m (4.5 m^2) consisting of the two middle rows with 20 plant stands from where data were collected. Distance between check basin and replicate was 1m. The seeds of each landrace were broadcast into the nursery bed of 1 m x 1 m and raised for 45 days. The beds were covered with dry grass mulch until emergence and watered using watering can as needed. A shade was made using palm fronds on top of the nursery beds to protect the seedlings from harsh weather conditions and subsequently removed for hardening a week before transplanting (at 35 days). Watering was carried out every other day using watering can. A week before transplanting, water supply to the nursery was also reduced in order to harden the seedlings and reduce transplanting shock. The seedlings were then watered on the bed to enhance easy uprooting to prevent too much root damage. Healthy and uniformly sized seedlings (well established seedlings) at a height of 20 – 25 cm were selected and transplanted into the pots in the screen house and the experimental field in check basins (Mebratu *et al*., 2014). Seedlings were transplanted out simultaneously in the screen house and the field. Pots of 30 cm depth and 25 cm diameter were filled with 8 kg of top soil each. The pots were perforated at the bottom and a thin layer of gravel stones were placed on it followed by a thin layer of mulch to ensure good drainage. The pots were arranged according to the treatment and placed on iron benches in the screen house. One seedling was transplanted into each pot. Also, seedlings were transplanted at 30 cm intra row spacing in the field. Plants were irrigated in the screen house using a watering can. In the open field system, the field was irrigated using a pumping machine at three days intervals to ensure the field was kept moist (at field capacity) throughout the growth period. Weeding was done at 3, 6 and 9 weeks after transplanting (WAT). Organic fertilizer was incorporated into the soil at two weeks before transplanting as per the treatment in both pot and field experiments. Six plants from each net plot were randomly tagged for determination of the following growth and yield parameters; plant height, number of leaves, number of fruits, fruit length, fruit diameter and fruit yield. The data obtained were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) software. Means were separated using Least Significant Difference (LSD) at $P \leq 0.05$.

Results

The physical and chemical properties of the soil before planting in the screen house and field, as well as the N, P and K contents of the organic fertilizer used are shown in Table 1. The textural classification of soil for screen house experiment was loamy sand and sandy loam in the field. The pH of the soil in water was slightly alkalinity and acidic in the screen house and field respectively. Organic carbon was low while total nitrogen was high in both sites. The phosphorus content was medium and low in the screen house and field respectively. The calcium was medium and high for screen house and field. The magnesium was high, potassium was low, sodium and CEC were medium in both sites. In the same vein, total N was high, available P was low and potassium was high in the organic fertilizer used in this study.

Organic fertilizer had a significant ($P<0.05$) effect on plant height at 6 and 12 WAT in both screenhouse and field conditions (Table 2). Application of organic fertilizer at 3.0 t ha^{-1} had taller plants but at par with plots given 1.5 t ha^{-1} at 12 WAT under the screenhouse condition. Similarly, application of organic fertilizer at 1.5 t ha^{-1} had the taller plants which were at par with plots given 3.0 t ha^{-1} under field condition. Application of 0 t ha^{-1} organic fertilizer had the shortest pepper plants in both conditions.

Table 1: Physical and chemical properties of the soil of the experimental sites and organic fertilizer used

	Screen house	Field	Organic fertilizer
Physical Size Distribution ($g\ kg^{-1}$)			
Sand	891.0	691.4	
Silt	42.0	96.0	
Clay	67.0	212.6	
Textural class	Loamy sand	Sandy loam	
Chemical properties			
pH in H_2O	7.61	6.85	
pH in $CaCl_2$	6.85	6.53	
Organic carbon ($g\ kg^{-1}$)	5.3	4.27	
Total N ($g\ kg^{-1}$)	1.54	2.1	2.17
Available P ($mg\ kg^{-1}$)	10.76	7.84	2.13
Exchangeable bases ($cmol\ kg^{-1}$)			
Ca^{2+}	4.64	5.20	
Mg^{2+}	1.5	1.20	
K^{+}	0.09	0.03	2.4
Na^{+}	0.16	0.11	
CEC ($cmol\ kg^{-1}$)	8.0	9.4	

Soil and organic fertilizer samples were analyzed in the analytical laboratory of the Department of Soil Science and Land Management, Federal University of Technology, Minna, Nigeria.

Planting of *Mgbakpa* and *Dan Sokoto* pepper landraces were significantly taller compared with *Dan Zaria* landrace at 12 WAT under screenhouse and 6 WAT under field condition (Table 2).

The interaction between organic fertilizer and landrace on hot pepper plant height at 6WAT under screenhouse was significant (P<0.05) (Table 3). In this case, irrespective of the landrace, there was an increase in the height of hot pepper plants as the organic fertilizer rate was increased from 0 to 1.5 t ha^{-1}, beyond this rate there was no significant response.

Table 2: Effect of organic fertilizer on plant height of some hot pepper landraces under screen house and field conditions in 2019/2020 dry season

	Plant height (cm)		Plant height (cm)	
	Screen house		Field	
	Weeks after transplanting		Weeks after transplanting	
Treatment	6	12	6	12
Organic Fertilizer (F) ($t\ ha^{-1}$)				
0	32.92b	79.25b	14.11b	27.67b
1.5	33.83b	92.33a	18.70a	37.69a
3.0	40.67a	98.33a	18.73a	37.48a
LSD (0.05)	5.35	10.25	2.26	6.88
Landrace (L)				
Dan Zaria	33.50a	81.50b	15.19b	31.10a
Dan Sokoto	37.67a	89.58ab	17.95a	34.84a
Mgbakpa	36.25a	98.83a	18.40a	36.89a
LSD (0.05)	5.35	10.25	2.26	6.88
Interaction				
F x L	**	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at ($P \leq 0.05$) by LSD.

Table 3: Interaction between organic fertilizer and some landraces on plant height of hot pepper at 6 WAT under screen house conditions in 2019/2020 dry season

	Landrace		
	Dan Zaria	Dan Sokoto	Mgbakpa
Organic Fertilizer (F) (t ha^{-1})			
0	29.50b	29.50b	28.00b
1.5	30.50b	43.00a	39.75a
3.0	40.50a	40.50a	41.00a
LSD (0.05)	9.09		

Means with the same letter(s) under the same column and row are not significantly different from each other at ($P \leq 0.05$) by LSD.

Number of leaves of hot pepper was significantly ($P<0.05$) increased due to organic fertilizer application (Table 4). At 6 and 12 WAT, under screenhouse, soil amended with organic fertilizer at 3 t ha^{-1} gave the highest number of leaves compared with pots amended with organic fertilizer at 0 t ha^{-1}. Similarly, at 6 and 12 WAT, under field condition, plots given organic fertilizer at 1.5 t ha^{-1} produced plants with the highest number of leaves, which was at par with plots given 3 t ha^{-1} organic fertilizer compared with the control (0 t ha^{-1}). However, in terms of the landrace, *Mgbakpa* at 12 WAT under screenhouse, had a significantly highest number of leaves compared to the other hot pepper landraces. Furthermore, at 6 and 12 WAT, under field condition, the use of *Dan Sokoto* and *Mgbakpa* produced similar highest number of leaves compared with *Dan Zaria* which had the lowest number of leaves.

Table 4: Effect of organic fertilizer on number of leaves of some hot pepper landraces under screen house and field conditions in 2019/2020 dry season

	Number of leaves		Number of leaves	
	Screen house		Field	
	Weeks after transplanting		Weeks after transplanting	
Treatment	6	12	6	12
Organic Fertilizer (F) (t ha^{-1})				
0	36.0b	192.0b	34.0b	180.0b
1.5	50.0ab	211.0b	46.0a	233.0a
3.0	61.0a	269.0a	44.0a	202.0ab
LSD (0.05)	14.56	42.73	9.79	50.01
Landrace (L)				
Dan Zaria	47.0a	192.0b	27.0b	155.0b
Dan Sokoto	50.0a	187.0b	49.0a	213.0a
Mgbakpa	50.0a	293.0a	47.0a	247.0a
LSD (0.05)	14.56	42.73	9.79	50.01
Interaction				
F x L	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at ($P<0.05$) by LSD.

Organic fertilizer application had significant (P<0.05) difference on number of pepper fruit per plant (Table 5). In both conditions, application of organic fertilizer at 1.5 t ha^{-1} and 3 t ha^{-1} produced similar highest number of hot pepper fruits per plant compared to 0 t ha^{-1} application.

In terms of the landrace, number of hot pepper fruits produced per plant was significantly (P<0.05) different among the hot pepper landraces used under field condition only (Table 5). In this case, the *Mgbakpa* landrace recorded the highest number of fruits per plant compare to *Dan Sokoto* landrace only. Similar longer fruits were recorded in plots given 1.5 and 3 t ha^{-1} organic fertilizers compared with 0 t ha^{-1} application in both screenhouse and field conditions (Table 5). Furthermore, longer fruits were obtained in plots with the *Dan Sokoto* landrace compared with that produced by *Dan Zaria* and *Mgbakpa* in both conditions (Table 5).

Hot pepper fruits were significantly bigger in plots treated with organic fertilizer at 1.5 t ha^{-1} compared with the other rates under field conditions only (Table 5). Pepper fruits produced by *Dan Zaria* and *Dan Sokoto* were significantly similar and bigger than the *Mgbakpa* landrace in both conditions (Table 5).

Hot pepper fruit yield was significantly higher in 3 t ha^{-1} organic fertilizer plots under screenhouse condition (Table 5). Furthermore, application of 1.5 and 3 t ha^{-1} organic fertilizer had a significantly similar higher fruit yield compared to hot pepper planted in 0 t ha^{-1} organic fertilizer plot under field condition. However, under landrace, fruit yield was highest in plots with *Dan Zaria* and *Dan Sokoto* landraces compared to plots with *Mgbakpa* landrace (Table 5).

Table 5: Effect of organic fertilizer on number of fruits per plant, fruit length and diameter, and fruit yield of some hot pepper landraces under screen house and field conditions in 2019/2020 dry season

	Screen house				Field			
Treatment	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit yield (kg ha^{-1})	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit yield (kg ha^{-1})
Organic Fertilizer (F) (tha^{-1})								
0	17.0a	2.05b	2.76a	2041.90c	15.0b	2.06b	2.46b	1225.40b
1.5	19.0a	3.19a	2.69a	4148.70b	31.0a	3.26a	2.69a	3938.10a
3.0	30.0a	3.36a	2.50a	6044.80a	23.0ab	3.17a	2.43b	3795.00a
LSD (0.05)	16.45	0.46	0.42	1404.20	11.78	0.29	0.23	426.28
Landrace (L)								
Dan Zaria	15.0a	2.40b	3.31a	4262.80a	23.0ab	2.25b	2.95a	2952.20ab
Dan Sokoto	28.0a	3.86a	3.17a	5537.50a	16.0b	4.14a	2.97a	3262.40a
Mgbakpa	23.0a	2.34b	1.48b	2435.20b	32.0a	2.11b	1.66b	2743.80b
LSD (0.05)	16.45	0.62	0.42	1404.20	11.78	0.29	0.23	426.28
Interaction								
F x L	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter(s) under the same column are not significantly different from each other at (P≤0.05) by LSD.

Discussion

The application of 1.5 to 3.0 t ha^{-1} organic fertilizer increased plant height, number of leaves and fruits, fruit length and size, and fruit yield of hot pepper in our study. The increase in growth and yield of hot pepper was due to the availability of nutrients and improved soil physical properties necessary for better crop development. This finding is in agreement with the work of Adesina *et al*. (2014) who reported an increase in vegetative growth and yield of hot pepper in treatment that received high organic fertilizer application.

Also, the result from the soil sample analyzed indicated that the soil was low in N, P, K and other micronutrients; thus, the positive response to the organic fertilizer observed. This finding is in agreement with Shehu *et al*. (2015) who reported that the Nigerian savanna soils are poor in inherent soil fertility status.

The tallest plants, and highest number of leaves produced by the landraces varied between *Mgbakpa* and *Dan Sokoto*. These landraces had better canopy development to trap solar radiation, for the production of more photosynthates which might have enhanced the source and sink relationship for higher growth and yield attributes. This result is similar to those of Quartey *et al*. (2014) who reported that genotypic differences may account for the variation in plant height and canopy formation among pepper genotypes. The highest number of fruits produced by *Mgbakpa* suggests its genetic ability to produce more fruits. This finding is in agreement with Sezen *et al*. (2011) who noted that fruit production in pepper, is usually influenced by genotypic and environmental conditions.

The production of consistently longer fruits by *Dan Sokoto*, bigger fruits and highest fruit yield by *Dan Sokoto* and *Dan Zaria* could be attributed to the ability of the two local landraces to efficiently utilize the growth factors, which might have supported the partitioning of more growth factors utilized towards the development of growth and yield attributes. Our result is consistent with previous study in which *Legon* 18 and *Anloga,* being farmers varieties (landraces) of hot pepper recorded highest undamaged fruits yield, suggesting their superiority to adapt to the local conditions compared to the other hot pepper genotypes (Quartey *et al*. 2014).

Conclusion and Recommendation

This study has shown that farmers in the Southern Guinea Savanna of Nigeria can obtain increased fruit yield of hot pepper with the application of 1.5 t ha^{-1} organic fertilizer in combination with *Dan Sokoto* or *Dan Zaria* landraces in dry season production, under irrigation. *Dan Sokoto* and *Dan Zaria* may be used in future breeding work.

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Recycling Human Urine for Amaranth Production and the Effect on Some Soil Fertility Properties

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Abstract

Soil has formed the bedrock of most agricultural production in the world especially in developing countries. Thus, this study aimed at evaluating the effect of human urine on soil fertility properties as compared with other fertilizers. The experiment was a 2-year field trial at the experimental field of the Department of Agronomy, University of Ibadan, Ibadan. The experiments were laid out in randomized complete block design (RCBD) with five treatments (undiluted urine, 1:4 urine-water dilution, NPK15-15-15, compost and the control) replicated four times. Each treatment was applied at the rate of 100 kg N/ ha. Amaranth (*Amaranthus viridis*) was the test crop, fresh amaranth biomass, dry matter yield and some soil fertility properties were examined. Harvesting was done fifth week after sowing for fresh and dry plant biomass. Results showed that soils treated with undiluted urine had the highest dry matter yield (14.3% 15.9%) ($P<0.05$) at the end of both cropping period, although it was not significantly different from other treatments compost, diluted urine and control (13.9%, 14.3% and 12.6%) except NPK 15-15-15 (10.5%) at first planting, it was significantly higher than other treatments at second planting. Urine fertilizer treatments increased the organic carbon content of the soil which house for nutrients in the soil. It was recommended that human urine can be used as substitute for inorganic fertilizer due to its high organic carbon content. The study established that undiluted urine compared favourably with mineral fertilizer.

Keywords:
Human Urine,
Amaranth,
Mineral fertilizer,
Compost,
Soil properties

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Le recyclage de l'urine humaine pour la production d'amarante et l'effet sur certaines propriétés de la fertilité du sol

Résumé

Le sol a constitué le fondement de la plupart des productions agricoles dans le monde, en particulier dans les pays en développement. Ainsi, cette étude vise à évaluer l'effet de l'urine humaine sur les propriétés de fertilité du sol par rapport à d'autres engrais. L'expérience était un essai de 2 ans sur le terrain de serre du Département d'agronomie de l'Université d'Ibadan, Ibadan. Les expériences ont été disposées en blocs complets randomisés (RCBD) avec cinq traitements (urine non diluée, dilution urine-eau 1:4, NPK15-15-15, compost et le contrôle) répétés quatre fois. Chaque traitement a été appliqué à raison de 100 kg N/ha. L'amarante (Amaranthus viridis) était la culture d'essai, la biomasse fraîche de l'amarante, le rendement en matière sèche et certaines propriétés de fertilité du sol ont été

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examinés. La récolte a été effectuée la cinquième semaine après le semis pour la biomasse végétale fraîche et sèche. Les résultats ont montré que les sols traités avec de l'urine non diluée avaient le rendement en matière sèche le plus élevé (14,3 % 15,9 %) (P<0,05) à la fin des deux périodes de culture, bien qu'il ne soit pas significativement différent des autres traitements compost, urine diluée et contrôle (13,9 %, 14,3 % et 12,6 %) sauf NPK 15-15-15 (10,5 %) à la première plantation, il était significativement plus élevé que les autres traitements à la seconde plantation. Les traitements aux engrais urinaires ont augmenté la teneur en carbone biologique du sol qui abrite les nutriments dans le sol. Il a été recommandé que l'urine humaine puisse être utilisée comme substitut à l'engrais conventionnel en raison de sa teneur élevée en carbone biologique. L'étude a établi que l'urine non diluée se comparait favorablement à l'engrais minéral.

Mots clés :
Urine humaine,
Amarante,
Engrais minéral,
Compost,
Propriétés du sol.

Introduction

African soils are gradually becoming non-agricultural friendly because of the alarming loss of nutrients and the unavailability to chemical fertilizers (Bationo *et al.,* 2012). One criterion for sustainable agriculture is efficient recirculation of plant nutrients (Kirchmann, *et al.,* 2017). Sustainable agricultural system could only be achievable when environmental, economic and social sustainability are put into consideration; hence the need for an eco-friendly farming which increases a healthy soil-plant-environmental system is necessary.

Eco-friendly farming could be achieved by converting waste products such as human urine to usable produce especially for agricultural purpose. Human urine which contains a high proportion of important nutrients in forms directly available to plants (Ranasinghe *et al.,* 2016, Pradhan *et al.*, 2007). It contains nitrogen in the form of urea, they are usually-pathogenic free, low in heavy metals concentration and it could be used as fertilizer to replenish and maintain a suitable soil- environment for crop production (Wen *et al.,* 2019). Human urine stored in a sealed container for over seven months increased the de-off rate of pathogen (WHO, 2006). However, treated human urine can be used as organic input in boosting soil fertility and enhancing food production (AdeOluwa *et al.,* 2016 and 2009). Adewole *et al.* (2013) elucidate that acceptability of urine as a fertilizer is a way of increasing farmers' gross margins. Pradahn *et al.* (2001) reported that, 90-100% of urine nitrogen is either urea or ammonium which is similar to that of artificial fertilizers. The P and K contents in urine are almost totally (95–100%) in an inorganic form which are directly available to plant. Urine has been successfully used to fertilize cucumber, cabbage, celosia, lettuce and tomatoes. The growth and yields were as good as could be obtained with mineral fertilization (KC *et al*., 2020, AdeOluwa *et al.,* 2016, Egigu *et al*., 2014,Cofie *et al.,* 2010, Pradahn *et al*., 2007). The need to evaluate treated human urine on *Amaranth viridis* became necessary as the vegetable is one of the most commonly consumed vegetables in Africa and Asia (Das, 2017).

Amaranthus viridis belong to the family *Amaranthaceae*, sub-family Amaranthoideae, to the genus Amaranthus. The ability to grow in hot weather, and high nutritive value have made them popular vegetable crops (Deepthi *et al.,* 2021), perhaps the most widely eaten vegetables in the humid tropics of Africa and Asia When the whole plant is harvested, a yield of 20-25 t/ha is obtainable while harvesting of shoots only (succession harvesting) gives a yield of 30-60 t/ha. Amaranth contains a wealth of minerals, it offers calcium, magnesium, potassium, phosphorus, and iron (Rastogi*et al.* ,2013). Amaranth oil is therapeutic for cardiovascular disease (CVD) and hypertension (Martirosyan *et al.,* 2007). All year cultivation of Amaranth in the tropics is gaining attention; therefore sustainable production of Amaranth is inevitable.

Objectives

The objectives of the study are;

To evaluate the effect of human urine in sustainable production of Amaranth

To evaluate the effect of human urine on some soil properties

Materials and Methods

Experimental site: The study was carried out at the Department of Agronomy, University of Ibadan, Oyo State, Nigeria ($7^0$24'N, $3^0$54'E, 234m above sea level).

Experimental design: The experiments were laid out in randomized complete block design (RCBD) with five treatments replicated four times.

Treatments: undiluted urine, 1:4 urine- water dilution, NPK15-15-15, compost and the control (no fertilizer)

Treatment collection: The urine used was collected from Kuti hall of residence, University of Ibadan and was stored in an air tight plastic container for 12 month. The compost and NPK was obtained from the soil fertility unit Department of Agronomy, University of Ibadan, Ibadan.

Period of planting: The experiment was carried out in two different years (2011 and 2013).

Plot dimension: Each experimental plot has dimension of 1.8 m x1.15 m and 0.5 m within plot. The spacing was 40cm in-between rows, while the drills were 2cm deep. There were six rows per bed.

The experimental field was cleared manually and followed by seedbed preparation. Amaranth was propagated by seeds through the process of drilling and it was thinned to an average of about 373 plants per bed which is proportionate to the average plant population per hectare.

Rate and time of application: Each treatment was applied at the rate of 100 kg N/ ha. Compost was applied two weeks before planting while other fertilizers were applied two days before planting.

Weeding and pest control: Weeding was done manually and insect were controlled using neem oil extract at the rate of 10ml of neem extract to1 litre of water.

Harvesting: This was done five weeks after planting. Plant biomass and relative dry matter yield were obtained after harvesting.

Data Analysis: All the parameters measured were subjected to analysis of variance (ANOVA) and means were separated using Least significance difference (LSD) at p (<0.05).

Results

Table 1 reveals the nutrient content of human urine used for the study. The urine contained 0.48% of nitrogen, 0.01% phosphorus and potassium.

In Table 2, the pre-planting chemical property of the soil showed that the soil was slightly alkaline 7.4 at first year but it was at neutral zone for the second year 7.1. The total nitrogen in the soil for the first and second planting is below the lower limit of critical range for N 1.5-2.0 g/kg with a value of 0.6 g/kg and 0.4

g/kg. The organic carbon content of the soil is above the critical range of soil organic carbon 10-14 g/kg at 18.0 and 24.9 g/kg respectively. The soil potassium 0.4 cmol/kg is on the high side of the critical range 0.2-0.4cmol/kg of K for tropical soils for the first year but normal 0.26 cmol/kg for the second year.

Table 1: Proximate analysis of human urine used

Parameters	Ph	Moisture content	Total solid	Urea	Ammonia	Total nitrogen	potassium	phosphorus
Values (%)	9.2	96.8	3.2	0.05	0.03	0.48	0.01	0.01

Table 2: Pre-planting physical and chemical properties of soil used at the depth of 0-15cm

	Measured values	
Parameters	First year	Second year
pH(H_2O)	7.4	7.1
Org C (g/kg)	18.0	24.9
Total N (g/kg)	0.64	0.4
Available P (mg/kg)	11	70
Exchangeable cation (cmol/kg)		
Ca	1.3	12.2
Mg	2.6	3.13
K	0.4	0.26
Na	0.6	1.3
Micronutrients (mg/kg)		
Mn	122	349
Fe	158	124
Cu	15	17.6
Zn	27	15
Particle size analysis (g/kg)		
Sand	832	830
Silt	60	64
Clay	108	106
Textural class	Loamy sand	Loamy sand

Table 3 established that NPK fertilizer had the highest fresh weight of amaranth 14.38 g/plant (25.88 t/ha) at harvesting which was not significantly different from that of undiluted urine 10 g/plant (18 t/ha) but was considerably better than the urine-water dilution treatment 7.69 g/plant (13.84), compost 5.38 g/plant (9.68) and control 5.38 g/plant (9.68g) for the first year. At the second year harvesting, undiluted urine had the highest fresh weight of amaranth 18.01g/plant (32.4t/ha), followed by NPK 15.19 (27.34t/ha) which were insignificant from each other but they performed better than Urine- water dilution treatments 14.80 g/plant (26.64t/ha), Compost 9.77 (17.58t/ha) and control 8.59 (15.64t/ha).

The result in Figure 1 revealed that at the end of the first year planting undiluted urine had the highest dry matter yield of 14.4% although it was not significantly different from other treatments except NPK which is 10.5%. Urine-water dilution had 14.3%, compost had 13.9% and control 12.6%. Plants grown on soils amended with undiluted urine still had the highest dry matter yield at the end of the second year planting 15.9% and were considerably higher from other treatments. However there was no significant difference between plant grown on compost on compost which was 14.2%, NPK 14.2% and control 14.3%, although they were better from plant grown with 1:4water- urine dilution which was 13.6%.

Table 3: Effect of fertilizer treatments on amaranth biomass

Treatment	First year ← g/plant	Second year →
Control	5.38	8.59
NPK(15:15:15)	14.38	15.19
Compost	5.38	9.77
1:4urine-water dilution	7.69	14.80
Undiluted urine	10.00	18.01
LSD(=0.05)	5.80	4.78

LSD=Least significant difference

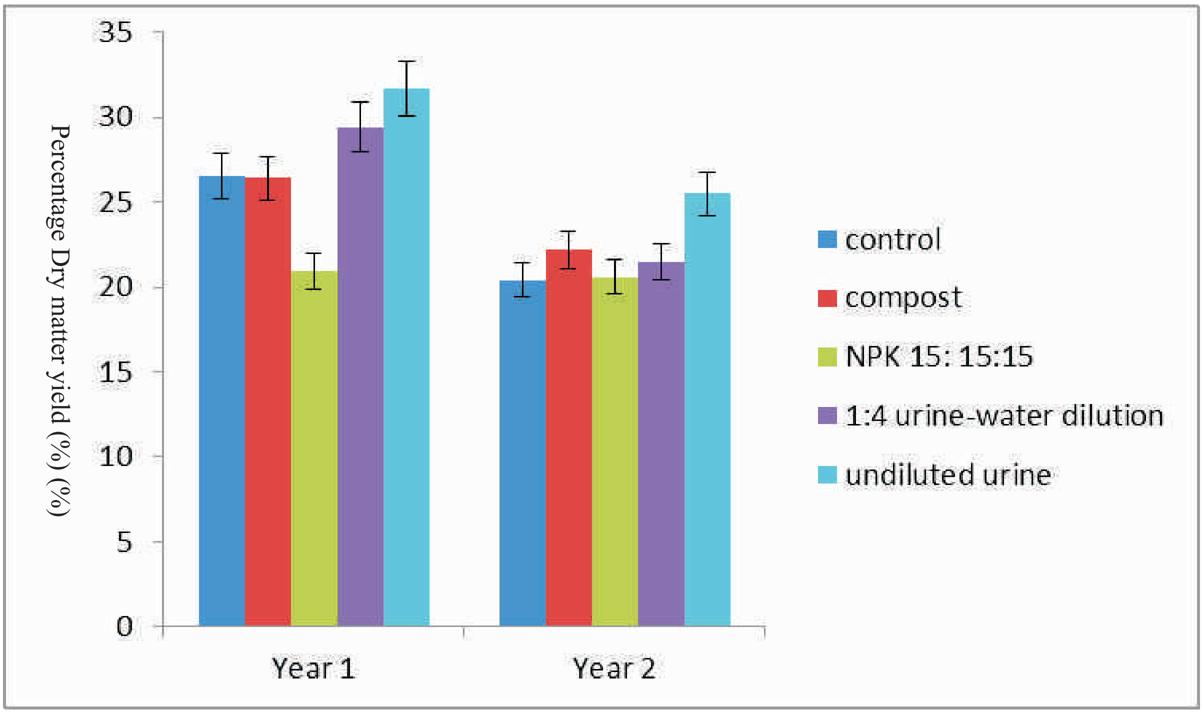

Figure 1: Dry matter yield of *Amaranth viridis* for year 1 and 2

The result of the soil analysis after first year planting is shown in Table 4. Soil pH remained the same for both undiluted urine and compost when compared with the results of the pre-planting soil analysis. However the soils treated with 1:4 urine-water dilutions 6.6 and NPK 6.7 became acidic while control 6.9 is neutral. The organic carbon content of the soil decreased by half for the 1:4 urine-water dilutions 16.57 g/kg as well as the NPK 13.39 g/kg. It also decreased slightly in the case of the control plot 30g/kg. However, there was an increase in the organic carbon content of the soils treated with compost 44.48 g/kg and undiluted urine 40.34 g/kg far above the critical range of organic matter of tropical soils. The nitrogen contents of all the soils depleted by great amounts from their initial pre-planting level which was 0.64g/kg. The textural class of the soil remained loamy sand for all after planting.

The result of the soil analysis after second year planting is shown in Table 5. Soil pH became acidic for NPK 6.7 when compared with the result of the pre-planting soil analysis 7.1. However the soil treated with compost 7.5 and 1:4 urine- water dilutions 7.5 tends towards alkalinity while undiluted urine 7.2 and control 7.3 remained at the neutral range for tropical soils. The organic carbon content of the soil decreased to almost half for control 7.5g/kg as well as 1:4 water-urine dilution 11.1g/kg, these are below the critical range of organic carbon 20-30g/kg. There was a slight increase in the organic carbon content of the soils treated with NPK 15.9g/kg compared to initial organic carbon of the soil before planting, there were high increase in soils treated with undiluted urine 17.1g/kg and compost 20.1g/kg. The nitrogen content of all the soils depleted by great amount from their initial pre-planting level.

Table 4: Post-planting physical and chemical property of soil subjected to treatments (1^{st} year)

Parameters	Measured value				
	NPK	Compost	Control	Undiluted Urine	1:4Urine-Water Dilution
pH (H_2O)	6.7	6.9	7.4	7.4	6.6
Org C (g/kg)	10.8	25.8	17.4	23.4	9.6
Total N (g/kg)	0.31	0.31	0.11	0.06	0.17
Particle size analysis (g/kg)					
Sand	812	872	792	772	852
Silt	10	4	10	12	6
Clay	88	88	108	108	88

Table 5: Physical and chemical properties of the soil after second planting (2nd year)

Parameters	Measured value				
	NPK	Compost	Control	Undiluted Urine	1:4Urine - Water Dilution
pH (H_2O)	7.5	7.4	7.2	7.5	7.4
Org C (g/kg)	27	27.6	26.4	7.8	9.6
Total N (g/kg)	0.17	0.06	0.25	0.14	0.42
Particle size analysis (g/kg)					
Sand	812	872	792	772	852
Silt	10	4	10	12	6
Clay	88	88	108	108	88

Discussion

The result obtained during the planting season clearly shows the importance of fertilizer in amaranth production, which aligned with Ocheving *et al*. (2019) that amaranth is a heavy feeder so it should be fertilized. It is also in line with the fact that amaranth requires a high amount of readily available nitrogen as stated in 2010 by the Directorate Plant Production South Africa that "one of the essential elements, and one which participates directly as an indispensable requirement for normal amaranth growth, is nitrogen" high level of N are essential for the re-growth of leaves after harvesting. N requirements may vary from 50 to 200 kg N/ha. The value of this study is in the fact that undiluted urine can serve as a substitute for inorganic fertilizers as it even gives a higher dry matter yield, the result is in tandem with (Karak *et al.,* 2011) that states that human urine can be used as a substitute for mineral fertilizer. The experimental field had low fertility with respect to nitrogen and this could be accountable for the response of the amaranth to fertilizer application. Ekpo *et al.* (2012) attest to the fact that Nigerian soils are depleted of nitrogen.

The study established that undiluted urine had higher dry matter for both planting year than mineral fertilizer. This is in tandem with the result of AdeOluwa *et al.,* (2012) that human urine increases the dry matter yield of some crops. Also Karak *et al.,* (2011) reported that human urine compared favourably with mineral fertilizers.

Conclusion

The study revealed that undiluted urine compared favourably to inorganic fertilizer NPK. Urine fertilizer treatments improve store nutrient reserve of the soil thereby leaving the soil in a more sustainable state for further cultivation of crops. Therefore undiluted urine can be used as a substitute for inorganic fertilizer NPK in sustainable production of Amaranth in the tropics.

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Residual Effect of Different Phosphorus Sources on Growth and Nodulation of Soybeans

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Abstract

A pot experiment was carried out at the screen house of the School of Agriculture and Agricultural Technology, Gidan Kwano campus, Minna during the cropping season of 2020. The research aimed at evaluating the effect and residual effect of different phosphorus sources on the growth and nodulation of soybean. Four seeds of TSB 4810 variety of soybean were planted per pot containing 2 kg of soil collected from 3 locations. A week after sowing plant was thinned to two seedings per pot. This was followed with the application of N, P, K, Mg and micro nutrients (B, Mo, Zn). Thereafter, the crop was fertilized as follows: control at 0 kg P ha^{-1}, organic P of bone meal source at 30 kg P ha^{-1}, inorganic P of Single Super Phosphate at 30 kg P ha^{-1} and AMF *Glomus Intaradices* (4 g pot $^{-1}$) received by soils obtained from Maikunkele, Maitumbi and Gidan Kwano. Treatments were then arranged in a Completely Randomized Design (CRD) replicated three times. Data collected were subjected to Analysis of Variance (ANOVA). Means were separated using Least Significant Different (LSD). Results obtained at first planting showed that the best shoot and root weights and the second best nodulation characteristics were obtained when organic P of bone meal source was applied. The second planting did not receive fresh doses of fertilizer treatments and the result obtained at the second planting showed that, except for of root weight, inorganic P improved growth and nodulation of the TSB 4810 soybean variety while organic P could not improve any of the growth characteristics compared to the control. Since soybeans performed significantly better at first planting with the application of fertilizer than second planting with residual fertilizer effect. As a recommendation, farmers should therefore apply fresh doses of phosphorus fertilizer yearly.

Effet résiduel de différentes sources de phosphore sur la croissance et la nodulation du soja dans

Résumé

Une expérience en pot a été réalisée à la serre de l'École d'agriculture et de technologie agricole, campus Gidan Kwano, Minna pendant la saison culturale de 2020. La recherche visait à évaluer l'effet et l'effet résiduel de différentes sources de phosphore sur la croissance et la nodulation de soja. Quatre graines de la variété de soja TSB 4810 ont été plantées par pot contenant 2 kg de terre collectée à 3 endroits. Une semaine après le semis, la plante a été éclaircie à deux semis par pot. Cela a été suivi par l'application de N, P, K, Mg et de micronutriments (B, Mo, Zn). Par la suite, la culture a été fertilisée comme suit : témoin à 0 kg P ha-1, P biologique de source de farine d'os à 30 kg P ha-1, P conventionnelle de Super Phosphate Simple à 30 kg P ha-1 et AMF Glomus Intaradices (Pot de 4 g -1) reçu par les sols obtenus de Maikunkele, Maitumbi et Gidan Kwano. Les traitements ont ensuite été disposés dans un plan complètement randomisé (CRD) répliqué trois fois. Les données recueillies ont été soumises à une analyse de variance (ANOVA). Les moyennes ont été séparées à l'aide de la différence la moins significative (LSD). Les résultats obtenus à la première plantation ont montré que les meilleurs poids des pousses et des racines et les deuxièmes meilleures caractéristiques de nodulation ont été obtenus lorsque le P biologique de la farine d'os a été appliqué. La deuxième plantation n'a pas reçu de nouvelles doses de traitements d'engrais et le résultat obtenu à la deuxième plantation a montré que, à l'exception du poids des racines, le P conventionnelle améliorait la croissance et la nodulation de la variété de soja TSB 4810 tandis que le P biologique ne pouvait améliorer aucune des croissances. caractéristiques par rapport au témoin. Étant donné que le soja a obtenu de meilleurs résultats lors de la première plantation avec l'application d'engrais que lors de la deuxième plantation avec un effet d'engrais résiduel. Comme recommandation, les agriculteurs devraient donc appliquer de nouvelles doses d'engrais phosphoré chaque année.

Mots-clés:
Croissance, Localisation, Nodulation, Phosphore, Source, Soja

Introduction

Soybean (*Glycine max* L) is an annual herbaceous plant in the Fabaceae (legume or bean family) (Tefera, 2011). It is reported as the legume with the highest protein content and vegetable oil among the other crops produced (IITA, 2009). Soybean is an important crop component in the farming system of most parts of Nigeria (Olufajo, 1992). According to Olufajo (1992) in the traditional soybean growing areas of Nigeria, soybean is most commonly intercropped with cereal crops like maize, sorghum and millet. Soybeans contribute to enhancing the sustainability of intensified cropping system by improving soil fertility through nitrogen fixation, and soybeans are capable of fixing between 60kg and 168kg of nitrogen per year under suitable conditions (Rienke and Joke, 2005) thereby cutting down on the amount of nitrogen fertilizer to apply on the field in order to improve productivity.

Phosphorus (P) is one of the most important nutrients for soybeans crops, being absorbed from 0.2 to 0.4 kg ha^{-1}. The nutrient participates in many metabolic processes, such as in energy transfer [adenosine triphosphate (ATP)], photosynthesis, respiration and synthesis of nucleic acids and glucose. There are several sources of P in the soil. In this research, we are considering four sources of P namely soil P, organic P (bone meal), inorganic P (SSP) and bio-available P (Arbuscular Mycorrhizal Fungi). Tropical soils are deficient in P due to the poor parent material and strong fixation of P to colloids. Less than 0.1 % of the total is found in solution thereby limiting biomass productivity and adequate levels of available P in the soil. Therefore, phosphate fertilization is paramount in these soils (Akinrinde and Okeleye, 2005). The most important phosphorus sources in arable soils are chemical fertilizers, though 75 to 90 percent of the phosphorus is fixed with iron, calcium and aluminium in soil (Turan *et al*., 2006). In surface horizons of most soils, P also occurs in organic forms in amounts that can vary widely (from 20% to 90% of the total P). Phosphorus solubilizing bio fertilizers are carrier-based preparations containing living or dormant cells of micro-organisms like Arbuscular mydorrhizal fungi (AMF). AMF helps in increasing crop production by aiding solubilization of insoluble phosphorus and supply of other nutrients, vitamins and other growth factors thereby increasing plant growth (Gaur and Sunita, 2009).

Soybean is essentially sensitive to low phosphorus availability because the biological nitrogen fixation requires high levels of phosphorus. The phosphorus deficiency can limit the nodules formation while the phosphorus fertilization can overcome the deficiency (Akinrinde and Adigun, 2005). Hence this research set out to evaluate the growth and nodulation response of soybean to different phosphorus sources. The objectives are to:

i. Assess the effect and residual effect of phosphorus sources on the growth of soybean
ii. Determine the effect and residual effect of phosphorus sources on the nodulation of soybean

Materials and Methods

Study Area

The experiment was carried out in the screen house of the School of Agriculture and Agricultural Technology, Federal University of Technology Minna. Minna lies within the Southern Guinea Savannah Zone of Nigeria. Minna has a sub-humid climate with a mean annual rainfall of 1284 mm. Minna has an elevation of about 258.5m above sea level (Ojanuga, 2006).

Soil Sampling and Analysis before the first planting

Soils were sampled from three different locations (Maikunkele, Maitumbi, and GidanKwano) and from five farmers' plot per location with the aid of a sterilized auger at 10 points per plot and at 0-15cm soil depth. Soils per location were bulked, homogenized and a large portion was prepared for pot filling while 125g of soil per location was sieved through a 0.5 and 2mm sieve in preparation for physical and chemical properties determination according to standard methods described by ISRIC/FAO (2002) .

Soil Sampling and Analysis before the second planting

Two kilograms (2kg) of soils in pots that were used for the first planting were sampled with the help of a sterilized spoon and bulked according to treatment. Bulked soil was air dried in preparation for physical and chemical properties determination according to standard methods described by ISRIC/FAO (2002).

Treatments and Experimental Design

Experiments for both plantings was a 3 x 4 factorial arrangement that is 3 locations (Maikunkele, Maitunmbi and GidanKwano) that received four sources of phosphorus as follows: 30 kg P ha^{-1} of organic phosphorus (0.2 g of bone meal), 30 kg P ha^{-1} of inorganic phosphorus (0.3 g of Single Super Phosphate), Arbuscular mycorrhizal fungi (4 g pot^{-1}) and 0 kg P ha^{-1} (control) fitted to a Completely Randomized Design (CRD) replicated three times. Note that the soils for the second planting were not treated afresh.

Seed Sowing and Crop Management

Planting of TSB4810 was done by sowing four seeds per pot. This was later thinned to two seedlings per pot a week after planting. These pots had earlier received a basal application of 30kg P ha^{-1} as SSP, KCl at the rate of 60kg K ha^{-1}, $MgSO_4$ at the rate of 5kg Mg ha^{-1}, $ZnSO_4$ at the rate of 10kg Zn ha^{-1}, $(NH_4)_2MoO_4$at the rate of 0.1kg Mo ha^{-1}, $Na_2 B_4 O_7.5H_{2O}$ at the rate of 0.1 kg B ha^{-1}, Urea at the rate of 20 kg N ha^{-1}at first planting. Seedlings in the pots were watered with 50-100ml of water when necessary and weeds were hand-picked continuously till termination at 6 weeks after planting.

Harvesting and Data Collection

Harvesting for both first and second planting was done by removing the whole plant from the pot while nodules were detached and counted. The shoots were separated from the roots and the roots was rinsed in water. The shoots and roots were oven-dried to constant weight within 3 days at 65^0C

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) Treatment means were separated using LSD (Least Significant Difference) at a 5% level of probability.

Results

Table 1: Physical and Chemical Properties of Experimental Soil before 1st planting and before 2nd planting

	Maikunkele	Before 1st Planting Maitumbi	GidanKwano	Maikunkele	Before 2nd Planting Maitumbi	GidanKwano
Soil Parameter						
Particle Size						
distribution ($gkg^{-}1$)						
Sand	768	778	798	768	778	798
Silt	120	100	80	120	100	80
Clay	112	122	122	112	122	122
Textual Class	SL	SL	SL	SL	SL	SL
pH in H_20 (1:2.5)	5.6	5.0	4.8			
Control				6.40	6.27	6.27
AMF				6.13	6.18	6.38
SSP				5.26	5.10	5.27
BM				7.26	7.18	7.17
Available P	18.55	17.73	13.87			
Control				9.10	13.3	16.8
AMF				15.05	18.9	21.0
SSP				21.05	24.5	25.2
BM				15.05	18.9	21.0
Organic Carbon	3.5	3.4	1.4			
Control				3.36	2.76	3.30
AMF				3.24	3.18	3.48
SSP				3.30	3.60	3.30
BM				3.30	3.18	3.12

SL= Sandy loam, O. C= organic carbon, Available P= available phosphorus, pH in H2O
AMF=Arbuscular mycorrhizal fungi, SSP=Single super phosphate, BM= Bone meal

Table 2: Main Effect of P-sources and Location on Growth and Nodulation of soybean at first planting

Treatment	**Shoot Weight (g) plant^{-1}**	**Root Weight (g) plant^{-1}**	**Nodule Number (g) plant^{-1}**	**Nodule Weight (g) plant^{-1}**
P sources(P)				
Control	1.32	0.44	6.0	0.05
AMF	1.38	0.39	6.0	0.06
SSP	1.47	0.46	13.0	0.10
Bone Meal	1.59	0.72	8.0	0.07
LSD (0.05)	0.34	0.21	3.97	0.04
Location (L)				
Maikunkele	1.48	0.59	9.0	0.07
Maitumbi	1.43	0.47	9.0	0.08
GidanKwano	1.41	0.44	6.0	0.06
LSD (0.05)	0.29	0.18	3.44	0.03
Interaction				
P * L	*	**	NS	NS

Means with the same letters are not significantly different at $P > 0.05$
NS = Not significant at $P > 0.05$
*= Significant at $P < 0.05$
**= highly significant at $P < 0.01$

Table 3: Effect of interaction between P-sources and Location on Shoot weight (g/plant-1) at first planting

	Location		
P Source	**Mainkunkele**	**Maitumbi**	**GidanKwano**
Control	1.22	1.24	1.51
AMF	1.68	1.34	1.13
SSP	1.07	1.83	1.52
Bonemeal	1.95	1.33	1.48
LSD		0.35	

Table 4: Effect of Interaction between P-source and Location on Root weight (g/plant-1) at first planting

	Location		
P Source	**Mainkunkele**	**Maitumbi**	**GidanKwano**
Control	0.35	0.51	0.45
AMF	0.35	0.45	0.36
SSP	0.38	0.54	0.47
Bone meal	1.29	0.38	0.50
LSD (0.05)		0.22	

Table 5: Main Effect of P-sources and Location on Growth and Nodulation of soybean at second planting

Treatment	**Shoot Weight (g) plant^{-1}**	**Root Weight (g) plant^{-1}**	**Nodule Number (g) plant^{-1}**	**Nodule Weight (g) plant^{-1}**
P sources(P)				
Control	1.18	0.60	4.0	0.03
AMF	1.12	0.48	1.0	0.01
SSP	1.22	0.34	5.0	0.04
Bone Meal	1.18	0.36	2.0	0.02
LSD (0.05)	0.34	0.15	.154	0.02
Location (L)				
Maikunkele	1.14	0.38	6.0	0.05
Maitumbi	1.22	0.43	1.0	0.01
GidanKwano	1.16	0.53	2.0	0.02
LSD (0.05)	0.29	0.13	1.33	0.02
Interaction				
P * L	NS	NS	*	NS

Means with the same letters are not significantly different at P > 0.05
NS = Not significant at P > 0.05
* = Significant at P < 0.05

Table 6: Effect of Interaction between P- sources and Location on Nodule number plant -1 at second planting

	Location		
P Source	**Maikunkele**	**Maitumbi**	**GidanKwano**
Control	7.0	0.0	3.0
AMF	4.0	1.0	0.0
SSP	9.0	2.0	3.0
Bone meal	4.0	1.0	2.0
LSD (0.05)		0.91	

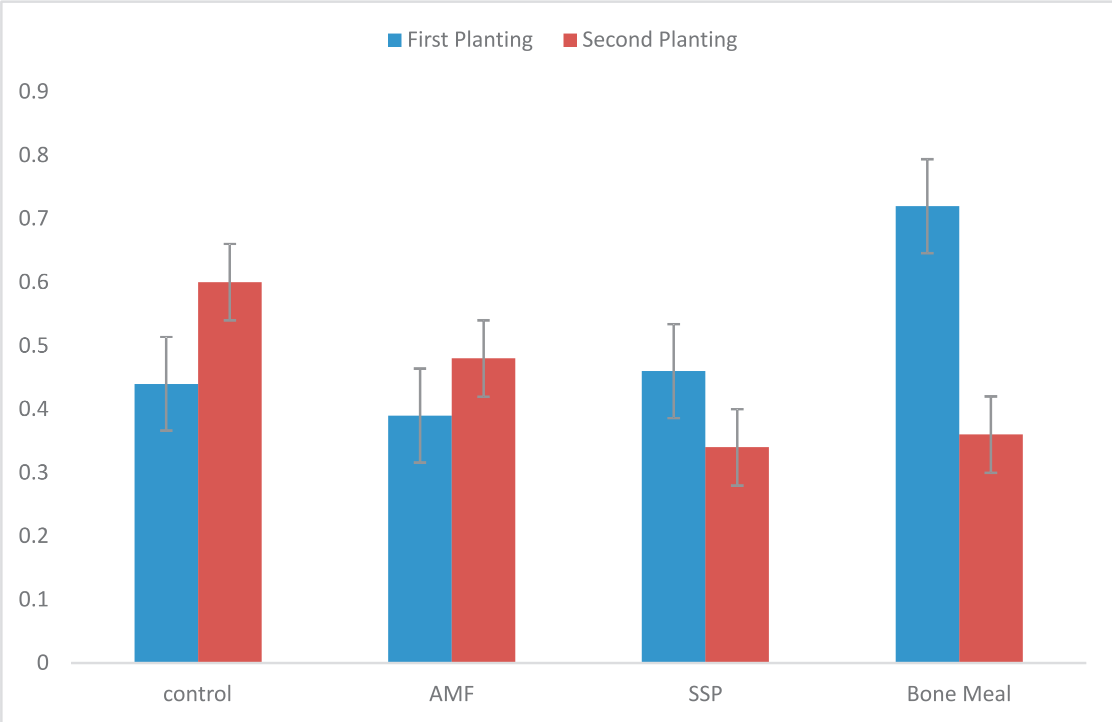

Figure 1: Residual effect of P sources on root weight of soybean

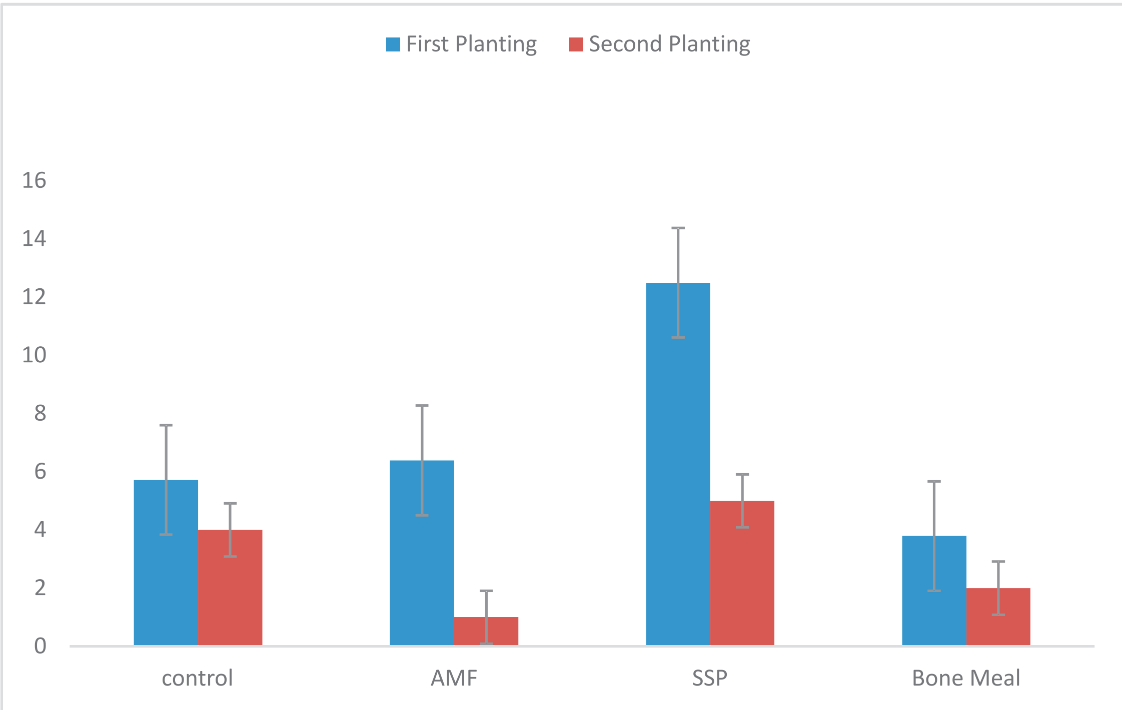

Figure 2: Residual effect of P sources on Nodule number of soybean

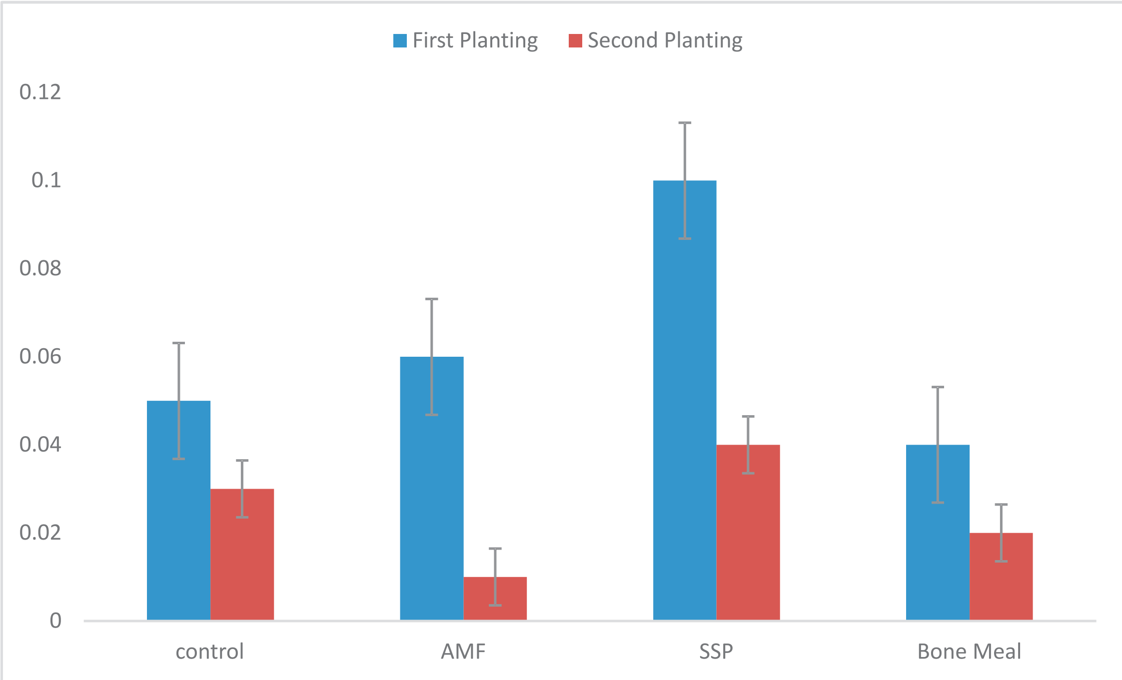

Figure 3: Residual effect of P sources on Nodule weight of Soybean

Discussion

Before the first planting, the soil textural class was sandy loam (Table 1). The textural class of soil before the second planting represented was also sandy loam(Table 1) indicating that soil texture may be fixed for a short period (https://biocyclopedia.com).

The highest shoot weight of plants was obtained in pots receiving no phosphorus application (Table 3). It might be an indication that the soybean variety was P-use efficient (PUE). This result has also demonstrated that the P-use efficiency varied with location with Gidan Kwano recording the highest, followed by Maitumbi and Maikunkele in that arrangement. According to Smith (2003), P-use efficiency is 15-20% in agricultural fields. The highest shoot weights of plants treated with bone meal (Table 3) may be an indication that organic P was most solubilized probably by natural AMF or some kinds of Phosphorus Solubilizing Microbes (PSM). Our result showed that Organic P solubilization also varied with location with Maikunkele recording the highest followed by Gidan Kwano and Maitumbi in that order. Gaur and Sunita (2009) also confirmed the activities of PSM in the release of P in bone meal.

The highest shoot weight of plants receiving inorganic phosphorus application (Table 3) may be an indication that their soil was the most P sufficient. This result has demonstrated that P sufficiency varied with location and also suggested that Maitumbi soil was the most P sufficient, followed by Gidan Kwano and Maikunkele in that arrangement. Smith (2003) reported that P-use efficiency (PUE) of 15-25% in agricultural fields was an indication that most of the soil- applied P remain unavailable to plant and leaches into ground and surface water leading to eutrophication.

Contrary to the trend observed under shoot weight, inoculation with AMF and zero P application produced root weights that were highest at Maitumbi, followed by Gidan Kwano and Maikunkele while the application of inorganic P reversed the order (Table 4). It is worthy to note that the application of P whether organic, bio-available or inorganic source did not always produce superior root weights compared to the control (Table 4). Rather, it was the application of bone meal at Maikunkele and Gidan kwano and the application of SSP at Maitumbi that did (Table 4). Root weights were highest in Maikunkele as a result of bone meal application for the same reason as shoot weight and also because the lowest clay content of Maikunkele soil (Table 1) reduced the binding capacity of its soil, hence improving solubility. Root weights were heaviest in Gidan Kwano (Table 4) as a result of bone meal application probably because of the efficient use of P in the bone meal due to the more acidic nature of their soil (pH in H_20 of 4.8) (Table 1). On the other hand, root weights were heaviest in Maitumbi as a result of the SSP application (Table 4). This might be because leaching was most minimized by the narrower ratio between sand and clay (6 : 1). Generally, an increase in root weight as a result of P application is because P increases energy storage and transfer via carbohydrate production and accumulation (Rasaq *et al.,* 2017). Similar to the trend observed under shoot weight, application of bone meal produced root weights that were highest at Maikunkele, followed by Gidan Kwano and Maitumbi in that sequence (Table 4). Reasons were the same as for those given for shoot weight response to bone meal.

Conclusion and Recommendations

Figures 1, 2 and 3 showed the residual effect on root weight, nodule number and weights respectively. The second planting produced the best root weights when no P and AMF were supplied to the plants respectively while the first planting produced the best root weights when SSP and bone meal were applied respectively (Figure 1). Regardless of the P source, the 1st planting produced the best nodulation (Figures. 2 and 3). This is surprising, since our results have demonstrated that the 1st planting resulted in improvement of the soil properties (Table 1) so that the 2nd planting was supposed to produce better plants at harvest. This suggested that regardless of P source, P was not efficiently used at the second planting. Although Kep *et al*. (2006) observed that one year after application of SSP in 4 soils, 58% of P application were available, 38% after 2 years and 20% after 3 years, our result has demonstrated that soil Available P was improved by 1st planting at Maikunkele by the addition of SSP, at Maitumbi by the application of SSP, AMF and bone meal respectively and at Gidan Kwano by all the P sources. The second planting could however not take advantage of it. Therefore farmers should continuously apply P fertilizer each time they plant. This is not because of the low residual effect per se, rather because of the low efficiency in the use of P applied in the first planting by crops planted after.

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Effects of Different Nitrogen Sources on Maize intercropped with Soybean on an Alfisols

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Abstract

A pot experiment was carried out at the screen house of the School of Agriculture and Agricultural Technology, Gidan Kwano campus, Minna in the cropping season of 2020. The experiment aimed to evaluate the growth and nodulation of soybean intercropped with maize. Two seeds of each crop were planted per pot containing 14kg of Gidan Kwano soils. A week after sowing, plants the were thinned to a seedling per crop genotype per pot, before basal application of N, P, K, Mg and micronutrients (B, Mo, Zn). Thereafter, the following cropping system (sole maize, sole soybean, intercropped maize and intercropped soybean) were fertilized as follows: -N as 0 kg N ha^{-1} (control), +inorganic N (urea) as 20 kg N ha^{-1} , +organic N (poultry dropping) as 20 kg N ha^{-1} and the United States Department of Agriculture (USDA) 110 as 5mls per plant of rhizobium inoculant. Subsequently, treatments were then arranged in a Completely Randomized Design with three replicates. Watering of plants was done daily till harvest at 6 weeks. Data collected were subjected to ANOVA. Means were separated using Duncan Multiple Range Test (DMRT). Results showed that averagely, sole maize was better than intercropped maize in plant height, the number of leaves and root weight but was significantly higher than intercropped maize in leaf area and shoot weight. Averagely, with the exception of days to 50% flowering and nodule weight, sole soybean was better than intercropped soybean in all the growth and nodulation characteristics measured. The sole soybean performed better when inoculated with elite strains of rhizobia USDA110 while the intercropped soybean was better when in association with indigenous rhizobium and 0 Kg N ha^{-1}. Organic Nitrogen of poultry source produced the best maize growth traits that was not significantly different as a result of inoculation of soybean with rhizobia.

Effets de différentes sources d'azote sur le maïs intercalé avec le soja sur un alfisols

Résumé

Une expérience en pot a été réalisée à la serre de l'École d'agriculture et de technologie agricole, campus Gidan Kwano, Minna pendant la saison de culture de 2020. L'expérience visait à évaluer la croissance et la nodulation du soja intercalé avec du maïs. Deux graines de chaque culture ont été plantées par pot contenant 14 kg de sols Gidan Kwano. Une semaine après le semis, les plants ont été éclaircis à raison d'un semis par génotype de culture par pot, avant l'application basale de N, P, K, Mg et de micronutriments (B, Mo, Zn). Par la suite, les systèmes de culture suivants (semelle de maïs, sole de soja, maïs intercalé et soja intercalé) ont été fertilisés comme suit : -N sous la forme de 0 kg N ha-1 (témoin), +N inorganique (urée) sous la forme de 20 kg N ha-1 , + N organique (déjections de volaille) à raison de 20 kg N ha-1 et le Département de l'agriculture des États-Unis (USDA) 110 à raison de 5 ml par plante d'inoculant de rhizobium. Par la suite, les traitements ont ensuite été organisés dans un plan entièrement randomisé avec trois répétitions. L'arrosage des plantes a été fait quotidiennement jusqu'à la récolte à 6 semaines. Les données recueillies ont été soumises à une ANOVA. Les moyennes ont été séparées à l'aide du Duncan Multiple Range Test (DMRT). Les résultats ont montré qu'en moyenne, la sole de maïs était meilleure que le maïs en culture intercalaire en hauteur de plante, en nombre de feuilles et en poids des racines, mais était significativement plus élevée que le maïs en culture intercalaire en surface foliaire et en poids des pousses. En moyenne, à l'exception des jours jusqu'à 50 % de floraison et du poids des nodules, le soya seul était meilleur que le soya intercalé pour toutes les caractéristiques de croissance et de nodulation mesurées. Le soja unique a obtenu de meilleurs résultats lorsqu'il a été inoculé avec des souches élites de rhizobium USDA110, tandis que le soja associé a été meilleur lorsqu'il a été associé à du rhizobium indigène et à 0 kg N ha-1. L'azote organique de source de volaille a produit les meilleurs caractères de croissance du maïs qui n'étaient pas significativement différents à la suite de l'inoculation du soja avec des rhizobiums

Mots-clés:
Culture intercalaire, Maïs, Azote, Sols, Soja

Introduction

Smallholder farmers are the most important food security stakeholders in sub-Saharan Africa (FAO, 2011). These farmers mainly practise subsistence agriculture characterized by low crop productivity due to the soil nutrient depletion. The majority of these farmers lack the financial resources to purchase sufficient amount of mineral fertilizers to replace soil nutrients removed through harvested crop products, crop residues, and through loss by runoff, leaching and as gases. Consequently, poor soil fertility has emerged as one of the greatest biophysical constraints to increasing agricultural productivity hence threatening food security in this region. It is imperative to adopt improved and sustainable technologies in order to guarantee improvements in food productivity and by extension, food security. Such technologies include the use of integrated soil fertility management practices (ISFM) such as improved intercropping systems of cereals with grain legumes as one of its main components (Mucheru-Muna, 2011).

Cereal-grain legume intercropping has the potential to address the soil nutrient depletion on smallholder farms. The legumes play an important role in nitrogen fixation, and are also an important source of nutrition for both humans and livestock (Nandwa, 2011). In the central highlands of Nigeria, cereal-legume intercropping is already being widely practised by the smallholder farmers where the most predominant are maize-common bean, maize-cowpea as well as maize- pigeon pea. According to Matusso (2014) intercropping cereal and grain legume crops helps maintain and improve soil fertility, because crops such as cowpea, mung bean, soybean and groundnuts accumulate from 80 to 350kg nitrogen (N) ha^{-1}. For instance, soybean can positively contribute to soil health, human nutrition and health, livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services than many other leguminous grain crops (Rakasi, 2011). Moreover, intercropping maize with soybean was reported to be proficient in terms of land utilization, in the western part of Africa. Although soybean is relatively a new crop for smallholder farmers in the central highlands of Nigeria, its cultivation is expected to gain popularity in the nearest future due to the increasing demand for food by families and fodder for their livestock. It is mostly intercropped with maize using the conventional 1:1 intercropping system, recommended by the Ministry of Agriculture. However, field trials conducted in West Africa precisely Nigeria showed an improved intercropping system of two rows of cereal followed by two rows of the leguminous crop has been observed to be more profitable than the conventional intercropping system. This is due to its efficiency in the use of resources, particularly land, nutrients, light and water. Nevertheless, intercropping of cereal-legume might lead to reduction in the yield of the legume component because of the adverse competitive effects.

Aim and Objectives of Study

This study aims to evaluating the effects of N sources on the growth of maize and soybean in an intercrop system of Minna.

The objectives of this study are to;

i. assess growth, root formation and nodulation of soybean in sole and intercropped system.

ii. assess growth and root formation of maize in sole and intercropped system.

Materials and Methods

Description of Study Area

The pot experiment was carried out in the screen house of the School of Agriculture and Agricultural Technology, Federal University of Technology Gidan Kwano, Minna, Niger State. Minna in the Southern Guinea Savannah Zone of Nigeria. Minna lies between longitudes 9^0 35'E and latitudes 6^0 33'N at an elevation of about 258.5m above sea level. The temperature rarely falls below 22^0 C. The peaks are 40^0C between February to March and 35^0C between November and December.

Soil Sampling and Analysis

Soil samples were collected randomly from Gidan Kwano at ten auger points per plot of five with the aid of a sterilized auger, bulked to form a composite. The composite was thoroughly mixed to form a soil. Thereafter, a larger portion was collected in pots while a smaller portion was reserved in the refrigerator for rhizobium population trials. Another small portion was air- dried in preparation for soil physical and chemical properties determination according to standard methods described by International Soil Reference and Information Centre and Food and Agricultural Organization (ISRIC/FAO, 2002).

Poultry N Content Analysis

The nitrogen content of the poultry droppings used was determined in the laboratory using the Kjeldahl method.

Treatments and Experimental Design

The treatments consist of Control (0 Kg N ha^{-1}), Inorganic Nitrogen of urea source (20 Kg N ha^{-1}), Organic Nitrogen of poultry source (20 Kg N ha^{-1}) and USDA 110 as Rhizobium inoculant at the rate of 5mls per plant. The treatments were replicated three times to give a total of thirty -six (36) pots.

Planting and Crop Management

The polythene pots used were filled with 14 kg of soil. The maize seeds (sammaz 15) and soybean seeds (TSB4810) were sown in polythene pots at the rate of two seeds (of each crop) per pot. Seeds were thinned to one crop per pot a week after planting. Organic nitrogen (poultry dropping) was added to the pots according to experimental design a week before planting. Single Super Phosphate (SSP) fertilizer was added to all the pots at planting. Basal applications of Single super phosphate, Muriate of Potash, Magnesium Sulphate, Zinc sulphate, Molybdate salt, boric acid and urea were supplied after thinning at the following rates ; 30 Kg P ha^{-1} , 60 Kg K ha^{-1}, 5 Kg Mg ha^{-1}, 10 Kg Zn ha^{-1}, 0.1 Kg Mo ha^{-1}, 0.1Kg B ha^{-1} and 20 Kg N ha^{-1}. Weeds were hand-picked before and after the basal application of nutrients and when necessary. Plants were watered to field capacity at a day interval till harvest six weeks after planting.

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA). Mean differences were separated using Duncan Multiple Range Test (DMRT) at a 5 % level of probability.

Results

Table 1: Initial Soil Properties Chemical properties of experimental location

Parameters (g kg)	Values
Sand	859.6
Silt	5.76
Clay	82.8
Textural class	Loamy sand
pH in H_2O (1:2.5)	6.95
Total Nitrogen (g kg^{-1})	1.68
Organic Carbon (g kg^{-1})	4.2
Available P (mg kg^{-1})	7
Poultry dropping (g)	7.83

Table 2: Main effect of N source and cropping system on Growth of maize

	PH (Cm)	LNO plant^{-1}	LA (Cm^3)	DSW g plant^{-1}	DRW g plant^{-1}
N source(N)					
Control	90.50b	8.00b	318.75b	11.53c	2.94b
Organic Nitrogen (PD)	102.00a	9.17a	370.55ab	16.46a	3.73ab
Inorganic Nitrogen(urea)	95.67ab	8.17ab	415.56a	15.81ab	3.34ab
+USDA 110 inoculants	89.83b	8.50ab	366.60ab	13.08bc	4.19a
LSD (0.05)	9.77	1.03	66.92	3.10	1.11
Cropping system(C)					
Sole maize	95.58a	9.17a	345.78a	12.32b	4.23a
Intercropped maize	93.42a	7.75b	389.95a	16.12a	2.87b
LSD (0.05)	6.91	0.73	47.32	2.19	0.78
Interaction N * C	NS	NS	NS	NS	NS

KEY: PH= Plant height; LNO= Leaf number; LA= Leaf area; DSW= Dry shoot weight; DRW= Dry root weight

Table 3: Main effect of N source and cropping system on the growth of soybean

	PH (cm)	NOB plant^{-1}	LNO plant^{-1}	LA cm3	50% flow	NN plant^{-1}	NDW g plant^{-1}	DSW g plant^{-1}	DRW g plant^{-1}
N source(N)									
Control	56.67b	8.0a	26.0b	39.75ab	32.0b	6.0b	0.08a	2.38ab	0.56ab
Organic Nitrogen (PD)	68.08b	8.0a	27.0ab	44.88a	32.0b	3.0c	0.05bc	3.19a	0.79a
Inorganic Nitrogen(urea)	59.67ab	6.0a	20.0c	33.44b	33.0a	3.0c	0.03c	1.78b	0.35b
+USDA 110 inoculant	82.17a	7.0a	31.0a	41.63ab	32.0b	14.0a	0.07ab	3.23a	0.54ab
LSD (0.05)	14.03	1.52	4.91	9.48	0.001	2.32	0.02	1.04	0.32
Cropping system(C)									
Sole soybean	84.29a	9.0a	34.0a	54.19a	30.0b	9.0a	0.05a	3.97a	0.91a
Intercropped soybean	49.00b	6.0b	17.0b	25.66b	34.0a	4.0b	0.06a	1.32b	0.22b
LSD (0.05)	9.92	1.07	3.48	6.70	0.001	1.64	0.02	0.73	0.22
Interaction N * C	**	NS	**	NS	**	**	**	*	NS

KEY: PH = Plant height NOB = Number of branches LNO= Leaf number LA= Leaf area NN= Nodule number NDW= Nodule dry weight DSW= Dry shoot weight DRW= Dry root weight.
Means with different letter(s) indicated on the column are significantly different at P≤ 0.05.
** = highly significant, NS = Not significant, * =Significant

Table 4: Plant Height (cm) as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	63.67bc	49.67cd
Organic N	81.50b	54.67cd
Inorganic N	75.0b	44.33c
+USDA 110	117.0a	47.33cd
SE±	6.62	

Table 5: Leaf Number per plant as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	29.0c	22.0de
Organic N	36.0b	17.0ef
Inorganic N	27.0cd	12.0f
+USDA 110	45.0a	17.0ef
SE±	2.32	

Table 6: Days to 50% flowering as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	31.0e	32.0d
Organic N	28.0f	36.0a
Inorganic N	31.0e	34.0c
+USDA 110	28.0f	35.0b
SE±	0.001	

Table 7: Nodule number per plant as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	4.0c	8.0bc
Organic N	2.0c	4.0c
Inorganic N	4.0c	2.0c
+USDA 110	26.0a	2.0c
SE±	1.09	

Table 8: Nodule dry weight per plant as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	0.06c	0.10a
Organic N	0.03c	0.07ab
Inorganic N	0.03c	0.03c
+USDA 110	0.10a	0.04bc
SE±	0.01	

Table 9: Dry shoot weight per plant as affected by the interaction between cropping system and N sources

	Sole soybean	Intercropped soybean
N Source (S)		
Control	2.83b	1.93bc
Organic N	4.85a	1.52bc
Inorganic N	2.82b	0.75c
+USDA 110	5.38a	1.07c
SE±	0.49	

Discussion

Soil Properties of the Experimental Location

The results obtained from the soil properties of Gidan Kwano soil (Table 1) showed that the soil textural class was loamy sand. Soil reaction was neutral which is the optimum for the growth of most plants as nutrients are most available to plants at the pH range of 5.5 to 7.0 (Miller and Donahue, 1995). The total nitrogen was very low. The organic carbon content of the soil was low which is characteristic of tropical soils resulting from the effect of high annual temperature and rainfall. Soil organic carbon is a potential soil fertility indicator for regulating nitrogen application in tropical farming systems. The soil's available phosphorus content was moderate. The total P concentration in crops generally varies from 0.1 to 0.5 percent, as such, moderate to a high content of phosphorus is required for maximum productivity of both maize and soybeans.

Growth and nodulation characteristics as affected by N sources.

Leaf area and shoot biomass were significantly affected by N sources (Table 2). This is because maize as a cereal crop requires an appreciable amount of nitrogen (90 – 120 Kg N ha^{-1}) to grow (Adesoji *et al.*, 2016). Maize in an intercrop system requires more nitrogen input. Since the association is with soybean, it is expected that the soybean would supply the amount of nitrogen sufficient through its association with effective rhizobia (Osunde *et al.*, 2003)

The best maize height and heaviest shoot weight were attained when 20kg N ha^{-1} was applied as organic N. There were more leaves and root weight was heaviest with the application of USDA 110 which is because the specie is capable of producing plant growth-promoting substances. The most important is indole acetic acid, an auxin resulting in higher root development (Perrig *et al*., 2007), and thus increasing the area of root system exploration and nutrient absorption (Ferreira *et al*., 2013).

Leaf area was widest with the application of Urea as an inorganic N source due to the fact that during the N assimilation and remobilization phases, young roots and leaves which are sink organs efficiently absorb and assimilate inorganic N for amino acids and protein synthesis (Hirel *et al*., 2007).

Inoculation with USDA was beneficial to sole soybeans compared to intercropped soybean with regards to plant height, the number of leaves, days to 50% flowering, nodulation and shoot weights (Table 4). This may be due to the fact that legumes are weak competitors in legume/cereal intercropping systems, compared with cereals (Hauggaard-Nielsen and Jensen, 2001). This is often ascribed to differences in the root distributions of legumes and cereals, and the resulting differences in the ability of these crops to compete for soil N (Fan *et al*., 2006).

Organic N was more beneficial to maize than the inorganic N when sole than when intercropped (Table 2). Generally, organic nitrogen is not readily available to plants because they are not in the form that can be taken up by plants due to the slow release of the nutrients. However, a plant rooting system and architecture affect the way nutrients are taken up. Maize plant with a prop rooting system are not deep feeders. Hence, sole maize that has no competitors has enough time to biodegrade and assimilate organic inputs than maize intercropped with soybeans. Intercropped soybean preferred natural rhizobial population and basal N than any other input. It has been well reported that N can be transferred from legumes to cereals in intercropping systems by indirect or direct pathways (He *et al*., 2009; Xiao *et al*., 2004). Indirect pathways transfer N released from dead and decayed legume tissues, and from legume root exudates to the rhizosphere, where they are taken up from the soil solution by cereal roots or hyphae. Direct N transfer is mediated by Common Mycorrhizal Network (CMN) between coexisting legumes and cereals (Paynel *et al*., 2008).

Interaction with native rhizobia (control) was also beneficial to intercropped soybean compared to other sources of nitrogen suggesting that the bioavailable nitrogen from the natural rhizobia was preferentially utilized by the legumes while the other forms of N (inorganic and organic N precisely) were utilized by the maize plants. Soybean and maize can be naturally inoculated by indigenous Arbuscular Mycorrhizal fungi and rhizobia in the field. Indigenous rhizobia have low nodulation activities than those of introduced rhizobia (Qin *et al.*, 2012). Therefore, effective rhizobium inoculation combined with indigenous AM fungi not only increases N uptake through symbiotic N fixation but also enhances N transfer by CMNs, which could subsequently contribute to improved intercropping advantages in soybean/maize intercropping system.

Conclusion and Recommendations

Although there were no significant differences between the different nitrogen sources and cropping systems in the growth of maize, the study has shown that soybean was significantly affected by the interaction between N sources and the cropping system. Sole soybean performed better when inoculated with an elite strain of rhizobium USDA 110 while the intercropped soybean performed better when in association with indigenous Rhizobium and 0 Kg N ha^{-1} (control).

It can therefore be recommended that intercropping maize with soybean will help supply a reasonable amount (60-70 %) of nitrogen required for optimum growth of the maize in association with soybean which can later be supplemented with the supply of 20 Kg N ha^{-1} as organic and inorganic sources to raise the crop to maturity. However, soybean in association with maize preferred natural rhizobial population such that inoculation with exotic rhizobia becomes needless and the cost of supply of biological nitrogen avoided or minimized.

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Immobilization of Nickel, Chromium and Cobalt and the growth of Sesame (*Sesamum indicum* L.) in Soils Amended with Compost and Biochar

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Abstract

This study was conducted to investigate the use of compost and biochar to reduce the concentration of chromium, cobalt, and nickel in soils and its effects on the growth of sesame. Soils were collected from the Agronomy Research Farm, University of Ibadan, Ibadan, Nigeria. Compost (Cp) and biochar (Bio) rates; Control, Cp4t/ha, Cp8t/ha, Cp12t/ha, Bio7t/ha, Bio14t/ha, and Bio21t/ha were applied to four kg of soil in pots at two weeks before planting in four replicates laid out in a Completely Randomized Design (CRD). Sesame plants were harvested after twelve weeks. Data on the chemical and physical properties of the soil and metals before and after planting, plant height, number of leaves, stem girth, and metal uptake in plant shoots and roots were collected. Data sets were subjected to Analysis of Variance using Genstat, (4^{th} Edition) and significant different means were separated using Duncan multiple range test at a five percent level of probability. Results showed that the concentrations of chromium, nickel, and cobalt in the soil were 69.5, 27.3, and 21.4 (mg/kg) respectively. Compost and biochar increased available P, exchangeable cations, and micronutrients in soils after sesame harvest while reductions in the concentrations of Nickel, cobalt, and chromium were recorded in biochar amended soil than in compost after harvest. Metals in sesame roots and shoots were higher in Biochar than in compost amended soil. The bioaccumulation factors of metals were above one (1) in the amended soils and were in this order; Cr> Ni > Co. Sesame height, number of leaves, and stem girth however increased in biochar and compost amended soils but not significant (>0.05). In conclusion, compost and biochar induced sesame growth and enhanced the immobilization of nickel, chromium, and cobalt.

Immobilisation du nickel, du chrome et du cobalt et croissance du sésame (*Sesamum indicum L.*) dans des sols amendés avec du compost et du charbon bio

Résumé

Cette étude a été menée pour étudier l'utilisation du compost et du biochar pour réduire la concentration de chrome, de cobalt et de nickel dans les sols et ses effets sur la croissance du sésame. Les échantillons (sables) ont été collectés à la ferme de recherche agronomique, Université d'Ibadan,

Ibadan, Nigeria. Taux de compost (Cp) et de biochar (Bio) ; Contrôle, Cp4t/ha, Cp8t/ha, Cp12t/ha, Bio7t/ha, Bio14t/ha et Bio21t/ha ont été appliqués à quatre kg de sol dans des pots deux semaines avant la plantation en quatre répétitions disposées dans un plan entièrement randomisé (CRD). Les plantes de sésame ont été récoltés après douze semaines. Des données sur les propriétés chimiques et physiques du sol et des métaux avant et après la plantation, la hauteur des plantes, le nombre de feuilles, la circonférence de la tige et l'absorption de métaux dans les pousses et les racines des plantes ont été recueillies. Les ensembles de données ont été soumis à une analyse de la variance à l'aide de Genstat (4e édition) et des moyennes significatives différentes ont été séparées à l'aide du test de plage multiple de Duncan à un niveau de probabilité de 5 %. Les résultats ont montré que les concentrations de chrome, de nickel et de cobalt dans le sol étaient respectivement de 69,5, 27,3 et 21,4 (mg/kg). Le compost et le biochar ont augmenté le phosphore disponible, les cations échangeables et les micronutriments dans les sols après la récolte du sésame, tandis que des réductions des concentrations de nickel, de cobalt et de chrome ont été enregistrées dans le sol amendé au biochar que dans le compost après la récolte. Les métaux dans les racines et les pousses de sésame étaient plus élevés dans le Biochar que dans le sol amendé au compost. Les facteurs de bioaccumulation des métaux étaient supérieurs à un (1) dans les sols amendés et étaient dans cet ordre ; Cr> Ni > Co. La hauteur du sésame, le nombre de feuilles et la circonférence de la tige ont cependant augmenté dans les sols amendés au biochar et au compost, mais non significatifs (>0,05). En conclusion, le compost et le biochar ont induit la croissance du sésame et amélioré l'immobilisation du nickel, du chrome et du cobalt.

Mots-clés:
Immobilisation,
Métaux lourds,
Compost,
Biochar et Sésame.

Introduction

Heavy metal concentrations in the environment and soil are on the increase due to mining and smelting activities and the application of phosphate fertilizers, pesticides, and sewage sludge (Adriano, 2001). Due to their persistent nature, plant growth is retarded and soil microorganism activities are hampered. Human life is endangered through the food chain as metals can be transferred into plant tissue (Kleckerová*et al*., 2013). In the view of Djingova and Kuleff (2000), The capacity of plants to accumulate necessary metals equally enables them to acquire other unnecessary metals." The chemical form in which the metal is found and its chemistry are what make them exist in crops and plants. Various remediation techniques based on either mobilization or immobilization processes have been developed to reduce the accumulation of heavy metals in the edible parts of crops and reduce their concentration in the soil to a less toxic level. The addition of organic materials such as compost, farmyard manure, and biochar to the soil can be used to mitigate heavy metal concentration in soils and enhance soil fertility. These materials may effectively reduce the bioavailability of these metals in the soil due to the high content of organic matter and high concentration of phosphorus. (Brown *et al*., 2003). According to Bernal *et al*. (2007), the use of biochar as a remediation technique is increasingly being recognized as a promising technology that can be used to remediate contamination in soils. Many studies have reported that biochar has been effectively used to immobilize and influence the bioavailability, bioaccessibility, and biotransformation of heavy metals in contaminated soil.

Sesame (*Sesamum indicum* L.) is a broadleaf crop belonging to the family Pedaliaceae. The genus consists of about thirty-six species, of which the most recognized is *Sesamum indicum L.,* popularly known as beniseed in Nigeria, and is cultivated in the Sudan and Sahel savanna and in the derived Southern and Northern Guinea (Alegbejo *et al.,* 2003). Depending on the varieties, sesame plants grow within 70-150 days after planting (Indu and Savithri, 2003). Sesame is used to feed livestock, prepare cosmetics, used in industries, and eaten by humans too (Sharma, 2005; El-Habbasa *et al.,* 2007). There is a paucity of information about the use of biochar and compost to immobilize metals from soil planted to sesame. Therefore, this study was conducted to determine the effect of compost and biochar on the growth of sesame plants and heavy metal concentration in soil and plant after harvest.

Materials and Methods

Experimental Location and Sample collection

This research was carried out in the screen house of the department of Soil Resources Management, University of Ibadan, Ibadan, Oyo State, Nigeria. It is located at latitude 7° 34' N and longitude 3° 54' E at an altitude of 234m. Topsoil was collected at a depth of 0-30cm from the Departmental Research Farm, Parry Road, University of Ibadan. Soil samples were passed through a 2mm sieve to remove the coarse and unwanted materials like stones, plant roots, and other debris. 4kg soils were weighed into a 4kg polyethylene pot (16.690cm^3). Soil samples were collected, air-dried, and their chemical and physical properties were determined.

Experimental Materials and Design

The experimental crop used was sesame (*Sesamum indicum* L.). The accession planted was NG/00/05/12/167. It was obtained from the National Centre for Genetic Resources and Biotechnology, Moor Plantation, Ibadan, Oyo State, Nigeria.

Other experimental materials included compost and rice husk biochar, which were used as amendments. The compost was obtained from Alesinloye Ibadan (Alesinloye compost) and the biochar was produced with a locally constructed Kiln (Haefele *et al*., 2011). The period of production was six hours at 350°C. The compost and biochar treatments applied to the soil were: Control- 0g/pot, Compost 4t/ha, 8t/ha and 12t/ha Biochar 7t/ha, 14t/ha and 21t/ha. The treatments were applied to the soil two weeks before planting so as to allow the materials added to mineralize laid out in a Completely Randomized Design (CRD) with four replicates. Each of the 4kg pot (16.690cm^3) was filled with contaminated soil collected from the Department of Soil Resources Management Research Farm, University of Ibadan. Nickel (Ni), chromium (Cr), and cobalt (Co) are major contaminants in polluted soils.

Planting Procedure and Data Collection

The soil was weighed into a perforated 4kg pot and moistened a day before planting. Four seeds of sesame were sown in each pot. The plants were thinned to two plants per pot one week after planting. The seedlings were carefully irrigated because the plants do not require a lot of water for their growth. Small plastics were placed under the pots to collect leached water for recycling. Hand weeding was also done to allow the proper growth of the plants and to reduce competition by weeds. Data were collected at 4, 6, 8, 10, and 12 weeks after planting. Data collected include plant height (cm), number of leaves per plant, stem girth (mm), total leaf area (cm^2), fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), and dry root weight (g). Plant height was measured in centimetres with a measuring tape. The numbers of leaves were manually counted while the circumference of the stem was measured (mm) for each plant using a veneer calliper and the value obtained was later converted to stem girth using the formula πD (where π= 3.142 and D= diameter).

Determination of Soil Properties

Soil samples were, air-dried and passed through a 2mm sieve for analysis before and after planting to determine their physical and chemical properties. The following chemical properties: soil pH, exchangeable cations (K, Ca, Mg, and Na), total nitrogen, exchangeable acidity, available P, exchangeable acidity, and organic carbon were determined based on the methods highlighted by Udo and Ogunwale (1986). Particle size analysis was done according to the method used by Gee and Or (2002).

Determination of Heavy Metal in Plant

After oven drying the shoots and roots of the plants to a constant weight, they were milled using a mortar and pestle. Heavy metal content in the plant tissue was determined with the atomic absorption spectrophotometer after digesting the milled samples with 5ml of nitric acid and perchloric acid in a fume cupboard (Mench *et al*., 1994).

Bio-accumulation factor (BF) was used to determine the quantity of heavy metals absorbed by the plant from the soil. This factor assesses the effectiveness of metal build up in plants and can be used to predict the phytoremediation efficiency of various plant species (Ghosh and Singh, 2005).

BF =Metal concentration in plant tissue/ initial concentration in plant tissue

The higher the BF value, the more suitable the plant is for phytoextraction (Blaylock *et al*., 1997).

Statistical Analysis

Data collected was subjected to Analysis of Variance using Genstat (4th Edition). Significantly different means were separated using the Duncan multiple range test at a 5% level of probability.

Results

Pre-planting Soil Chemical and Physical Properties

The soil used for the study was sandy loam with 77.6 % sand, 15.6 % silt, and 6.8 % clay (Table 1) as analysed and reported by Thomas and Omueti (2015). The soil pH (5.9) is low and falls below the range of most agricultural crops optimum pH (6-7). Low pH conditions may enhance metal solubility and possibly leach into underground water (Jason *et al*., 2016; Olayinka *et al*., 2017). The value obtained for soil organic carbon is 1.19%. The soil contained 3.1 g/kg of total nitrogen and 13 mg/kg of available phosphorus. The exchangeable cations present in the soil are 0.9 cmol/kg of potassium (K), 0.6 cmol/kg of magnesium (Mg), 6.3 cmol/kg of calcium (Ca), and 0.4 cmol/kg of sodium (Na). The soil also contained extractable micronutrients; 7 mg/kg of iron (Fe), 66 mg/kg of manganese (Mn), 3 mg/kg of copper (Cu), and 8 mg/kg of zinc (Zn). The chemical properties were above the critical levels reported by Chude *et al*., (2012) and it is an indication that the soil is fertile and will support plant growth. The concentrations of chromium, nickel, and cobalt in the soil were 69.5, 27.3, and 21.4 mg/kg respectively.

Chemical Properties of Amendments Used for the Study

The chemical properties of compost and biochar used as amendments in the study are reported in Table 2. The pH for compost and biochar was 8.5 and 7.1, respectively. Biochar is known to have an alkaline pH because of its carbonaceous composition (Krull 2012). The compost and biochar contained 1.9% and 0.8% of organic carbon, respectively, 0.8% and 0.4% of total nitrogen, 7.5% and 5.6% of phosphorus. The nutrients contents are 2.1% and 4.1% of potassium (K), 12.3% and 0.6% of calcium (Ca) 2.9% and 0.6% of magnesium (Mg) was found in the compost and biochar respectively. Selected chemical properties in compost were higher than those in biochar except for Ca and K. Nitrogen and phosphorus are reported to be low in biochar (Bridle and Pritchard, 2004). The additional nutrients in both biochar and compost will enhance plant growth.

Table 1: Pre-planting Soil Chemical and Physical Properties

Soil properties	**Values**	**Critical level (Chude *et al.*, 2012)**
pH (1:1, H_2O)	5.8	Neutral 6.6-7.2
Organic Carbon (%)	1.19	10-14
Total Nitrogen (g/kg)	3.1	1.6-2.0
Available Phosphorus (mg/kg)	13	7-20
Exchangeable Cations (cmol/kg)		
K	0.9	
Mg	0.6	0.31-0.6
Ca	6.3	
Na	0.4	
Extractable micronutrients (mg/kg)		
Fe	7	
Mn	66	
Cu	3	
Zn	8	
Heavy metals		
Cr	69.5	
Ni	27.3	
Co	21.4	
Particle size distribution (g/kg)		
Sand	776	
Silt	156	
Clay	68	
Textural class (USDA)	Sandy Loam	

Table 2: Chemical Properties of the Amendments Used for the Study

Nutrients	**Compost**	**Biochar**
Ph	8.5	7.1
Organic Carbon (%)	1.9	0.8
Total Nitrogen (%)	0.8	0.4
Phosphorus (mg/kg)	7.5	5.6
Exchangeable Bases (%)		
K	2.1	4.1
Ca	12.3	19
Mg	2.9	0.6

Effect of Compost (Cp) and Biochar (Bio) on Soil Chemical Properties after Sesame Harvest

The results of the effect of compost and biochar on soil chemical properties after sesame harvest were noticeable, as presented in Table 3. Among the treatments, 0 t/ha had the lowest pH (5.9). The application of compost and biochar increased the pH of the soil, Bio 21 had the highest pH (8.4). The addition of compost and biochar increased soil chemical properties. All the treatments increased soil pH though not significantly different at $p < 0.05$. However, a significant increase in pH was observed with the application of Bio 21. The application of biochar as an alkaline amendment, enhanced soil pH as recorded by some scientists (Chan *et al*., 2007; Lee *et al*., 2008; Ok *et al*., 2011a, b). The addition of compost also increased soil pH as a result of the release of basic cations into the soils (Erhart and Hartl, 2010; Leroy *et al.*, 2007). Both biochar and compost additions increased soil organic carbon, although Cp12 significantly increased organic carbon (25 g/kg) more than the other amendments. High soil organic matter content can decrease metal availability in soil, thereby reducing uptake by the plant (Eissa *et al*., 2016). An increase in soil organic matter content was reported to have decreased the concentrations of Cd and Ni in soil solution (Arnesen and Singh, 1999). Treatments applied reduced the total nitrogen at Cp4 (2.8 g/kg) and Bio7 (3.0 g/kg). Compost and biochar applied at different levels increased available P which was not significantly different from each other, even though Cp12 application increased available P (20.0 mg/kg). Marinari *et al*. (2000), showed a similar increase in soil P, after application of organic amendments. The highest significant value for Ca (8.1 cmol/kg) was recorded with Cp12. While Bio14 (3.1 cmol/kg) significantly increased Mg and the lowest value for Mg was recorded at Cp4 (0.8 cmol/kg). The addition of Bio21 significantly increased K (1.7cmol/kg). The highest value for Na was recorded at Bio21 (1.7 cmol/kg). The observed increase in Ca, Mg, Na, and K could be due to the high amounts of Ca, Mg, K, and Na in the amendments. This confirms the results of Khoshgoftarmanesh and Kalbasi (2002).

The different levels of treatments also increased soil micronutrients. The highest values (160 mg/kg and 10 mg/kg) were recorded for Mn and Cu at Bio14. Zn had the highest value (14 mg/kg) at Bio14 and Bio 21. Biochar applied at Bio 21 significantly increased soil Fe (123mg/kg) while there is a similar increase in the Fe content with the addition of compost than with the control. An increase in soil micronutrients was also reported by Antoniadis and Alloway (2003) with organic amendments. This could be due to an increase in soil organic carbon and pH after the addition of both compost and biochar.

Effect of Compost (Cp) and Biochar (Bio) on Heavy Metal Uptake by Sesame

An increase in the treatments resulted in a gradual decrease in heavy metal uptake by sesame (Table 4). Metal shoot uptake was highest in the control experiment with the concentrations of 33.2 mg/kg, 13.3 mg/kg, and 11.5 mg/k for chromium (Cr), nickel (Ni) and cobalt (Co) respectively. Significant Lowest chromium shoot uptake (5.5mg/kg) was observed with the application of Cp12t/ha. Nickel (Ni) in plant shoot had the lowest value (6.8 mg/kg) with the addition of Cp12t/ha and Cp8 for Cobalt shoot uptake (2.3mg/kg). Several studies have shown that the amendment of contaminated soils with organic materials such as compost reduces the bioavailability of heavy metals (Khan *et al*., 2000).

The Cp12 treatment resulted in significantly lower Cr (9.2), Ni (6.0), and Cobalt (4.0) root uptake than the control. Chromium and Nickel root uptake were higher than cobalt with all the treatments. Plants can uptake metals that has dissolved in soil solution, but the addition of organic amendments could reduce their uptake in plant roots and shoots according to the findings of Kumpiene *et al*., (2008) and Bolan *et al*., (2014). This study showed that compost and biochar influenced the reduction of heavy metal uptake by sesame plants. Soil metal bioavailability can be reduced by organic amendments. This will lead to a reduction in the metal uptake by the cultivated plant due to the altering of available forms to some unavailable forms. For example, fractions bonded to soil organic matter, carbonates, or Fe-Mn oxides (Walker *et al*., 2004). Out of the two amendments used, the significant reduction in metal bioavailability via sesame shoot and root by compost was similar to the findings of Irfan *et al*., 2021. Biochar has been reported to immobilize heavy metals by transforming the readily available fractions to geochemically more stable residual fractions, resulting in reducing the mobility and bioavailability of heavy metals (Ahmad *et al*., 2014).

Table 3: Effect of Compost and Biochar on Soil Chemical Properties after Sesame Harvest

Treatment	pH	O.C	TN	Av.P	Ca	Mg	K	Na	Ex.A.	Base Sat.	Mn	Cu	Zn	Fe
(t/ha)		g/kg		mg/kg	cmol/kg					g/kg	mg/kg			
0	5.9c	11.7d	1.5c	9.3c	4.7d	0.4c	0.6d	0.3d	0.8a	882.7d	62d	2e	7c	6c
Cp4	8.0bc	20.8c	2.8b	14.8ab	6.8c	0.8c	1.1bc	0.8c	0.5b	952.1c	121c	4d	9b	25b
Cp 8	8.1bc	22.1bc	3.9ab	16.5ab	7.5ab	1.2ab	1.3bc	1.0ab	0.5b	960.6ab	137ab	8c	12a	36b
Cp12	8.2b	25.9a	4.9a	20.0a	8.1a	1.6ab	1.4abc	1.2a	0.5b	962.1ab	144ab	9b	13a	44b
Bio7	8.2b	22.9abc	3.0b	13.2ab	7.4ab	0.9ab	1.0bc	0.8c	0.4b	959.5ab	144ab	5d	10b	27b
Bio14	8.3ab	24.1abc	4.2ab	13.5ab	7.9ab	3.1a	1.5ab	0.9ab	0.2c	982.5a	160a	10a	14a	40b
Bio21	8.4a	24.8ab	3.8ab	14.5ab	7.8ab	1.7ab	1.7a	1.7a	0.2c	983.8a	156a	9c	14a	123a

Cp-Compost, Bio-Biochar, Ex. A-Exchangeable acidity, ECEC-Exchangeable cation exchange capacity

Table 4: Effect of Compost and Biochar on Heavy Metal Uptake by Sesame

Treatment (t/ha)	Shoot (mg/kg)			Root (mg/kg)		
	Cr	Ni	Co	Cr	Ni	Co
0	33.2a	13.3a	11.5a	26.2a	21.0a	9.0a
Cp4	15.8b	8.8b	6.5b	17.5b	13.2b	8.5a
Cp8	9.8c	6.8abc	2.3d	12.5c	7.0c	4.2a
Cp12	5.5d	5.2c	2.0d	9.2d	6.0c	4.0a
Bio7	17.0b	8.5ab	6.5b	25.8a	10.5bc	8.5a
Bio14	15.8b	7.8ab	3.8c	23.2ab	8.0c	7.0a
Bio21	9.8c	6.8abc	3.3c	20.2ab	8.0c	5.2a

Cp- Compost, Bio- Biochar, Cr- Chromium, Ni- Nickel, Co- Cobalt

Table 5: Bio-accumulation Factor of Heavy Metals in Sesame Plant

Treatment (t/ha)	Cr	Ni	Co
0	7.9	3.1	1.2
Cp4	2.6	1.5	1.1
Cp8	1.5	0.8	0.5
Cp12	1.0	0.6	0.3
Bio7	4.3	1.4	1.2
Bio14	4.8	1.5	0.9
Bio21	3.8	3.5	0.8

Cp- Compost, Bio- Biochar Cr- Chromium, NI- Nickel, Co- Cobalt

The study revealed that the BCF of chromium by the plant for all the treatments was greater than 1 as shown in Table 5. This is similar to the report of Medyn´ska-Juraszek *et al.*, (2020) that the bioaccumulation factor of Cr value was >1. This signifies that the addition of amendments most especially Cp12 could enhance Cr transfer risk to the aerial parts of the plant. It is also an indication that the rate of bioaccumulation of chromium (Cr) was highest compared to nickel (Ni) and cobalt (Co). This same assertion could be deduced for Ni and Co as their bioaccumulation factor is > 1 under compost and biochar except in a few cases where the addition of Cp8 t/ha and Cp12 t/ha recorded values of <1 with 0.8 and 0.6 respectively for Ni and Cp8 t/ha, Cp12 t/ha, Bio14 t/ha and Bio21 t/ha with 0.5, 0.3, 0.9 and 0.8 respectively, for Co. This implies that under these treatments, Ni and Co transfer risk to the plant shoot and root could be minimal. Showing that sesame could accumulate more Cr than Ni and cobalt with the addition of Cp12. This corroborates the findings of Medyn´ska-Juraszek *et al*., (2020) that compost addition to soils could increase heavy metal concentration in some vegetable species, increasing adverse health risk.

Effect of Compost and Biochar on the Growth of Sesame

Compost and biochar increased sesame height successively, as shown in Figure 1. At 4WAP, there was no significant difference between the treatments. At 6WAP, the application of Cp12 had the highest plant height but was not significantly different from other treatments except Bio7 and control. From 8WAP to 12WAP, Cp12 had the highest plant height, but it was not significantly different from the other treatments applied except for the control. Biochar application has been reported to increase sesame plant height (Wacal *et al*., 2019). The effect of compost and biochar applied at different levels on the number of leaves, of sesame is presented in Figure 2. From 4 to 6WAP, the treatments had same the effect on the number of leaves. A noticeable increase in the number of leaves was observed from 6 to 12WAP with Cp12 having the highest number of leaves which was significantly different from the control. The effect of compost and biochar treatments at different levels on the stem girth of sesame, as presented in Figure 3, showed that plant stem girth increased with Cp12 and Cp8 across the weeks. At 4WAP, stem girth responded the same way to the treatments applied. At 6WAP, there was no significant difference in the response of stem girth to the treatments applied except for the control.

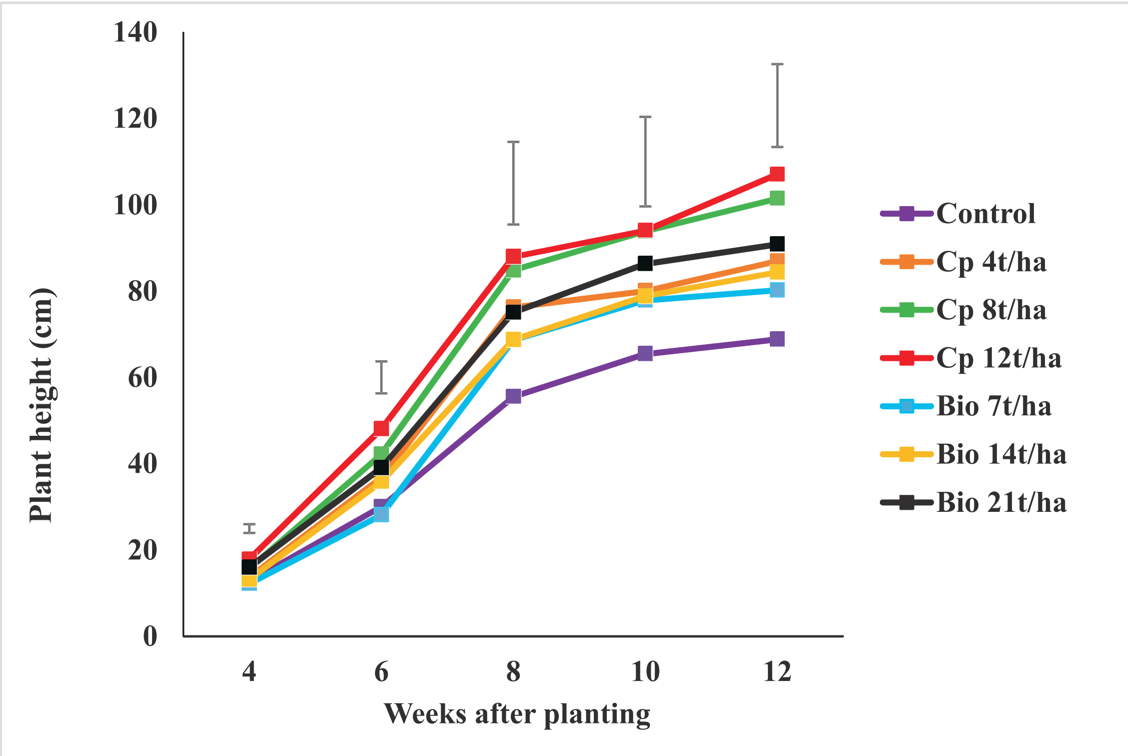

Figure 1: Effect of Compost and Biochar on Plant Height of Sesame
Cp- Compost, Bio- Biochar

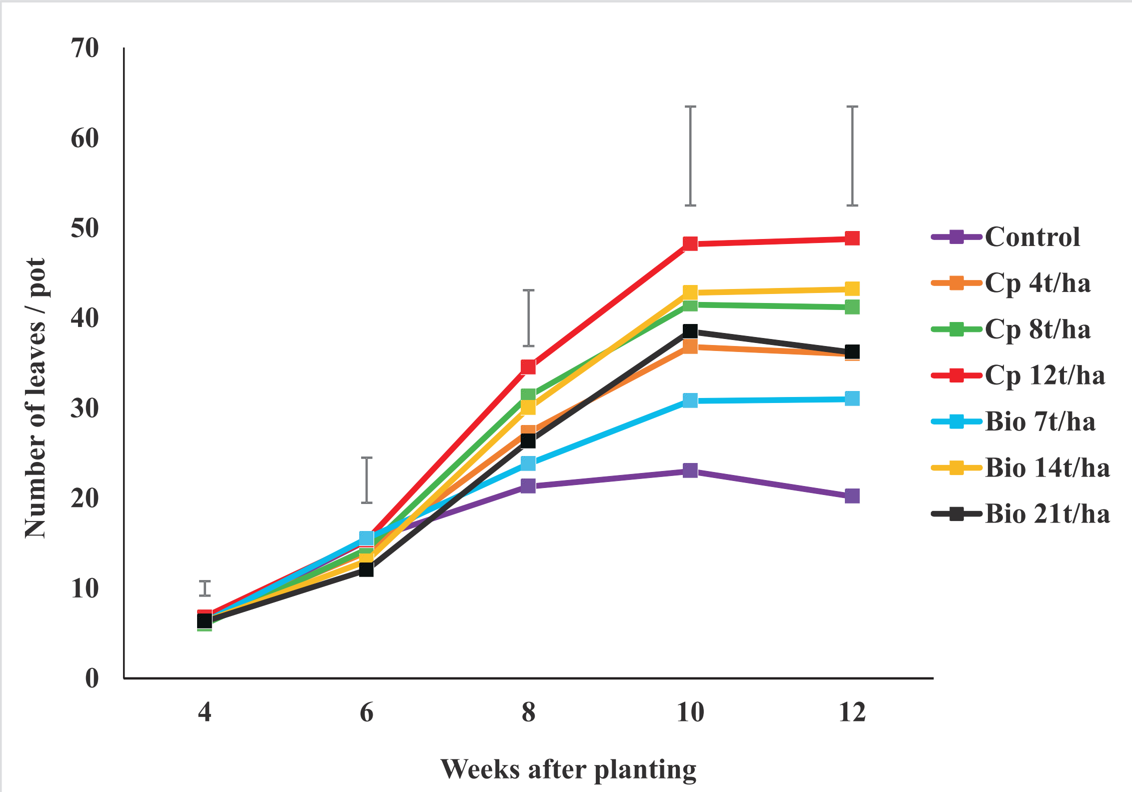

Figure 2: Effect of Compost and Biochar on Number of leaves of Sesame
Cp- Compost, Bio- Biochar

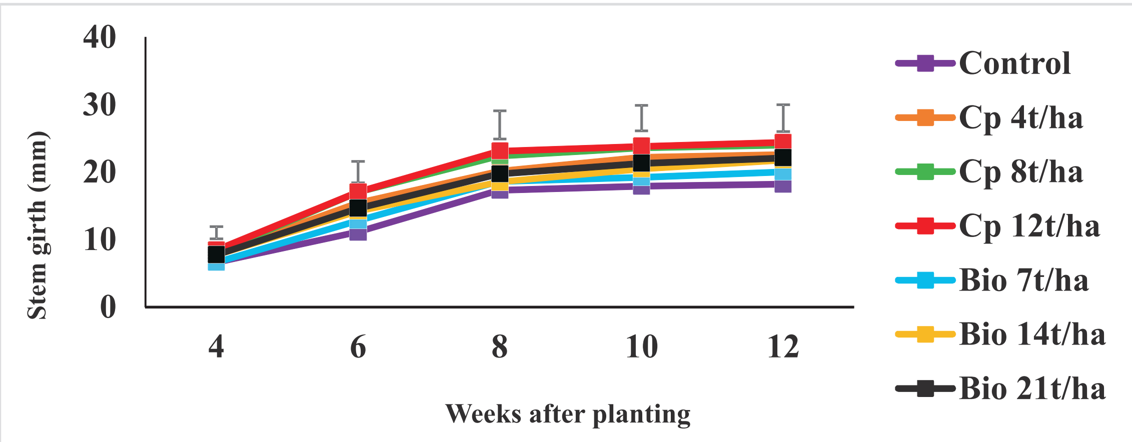

Figure 3: Effect of Compost and Biochar on Stem Girth of Sesame
Cp- Compost, Bio- Biochar

At 8WAP, Cp 12 had the highest girth and it was significantly different from Bio7, Bio14, and control. Poultry litter biochar has been reported to enhance cabbage stem girth in an experiment conducted by Ofori *et al*., (2021). From 10WAP to 12WAP, no increase in the stem girth was recorded. Stem girth responded better to Cp12 and Cp8, although they were not significantly different from other treatments except the control.

The increase in plant height, number of sesame leaves, and stem girth could be attributed to the inherent nutrients in compost and the ability of biochar to enhance the availability of nutrients by decreasing soil nutrients leaching when applied to soil (Kammann *et al*., 2015 and Sohi *et al*., 2009).

Conclusion

The addition of compost and biochar amendment had a positive effect on the adsorption of Cr, Ni, and Co and their uptake by plants compared to the control. The concentrations of metals were higher in the root than in the shoot of the plant. An increase in Cp and Bio treatments resulted in a gradual decrease in the total heavy metal uptake by sesame. Cp 12 t/ha and Bio21 t/ha reduced the concentration of Cr, Ni, and Co in the soil. Therefore, subsequent application of compost and biochar may help to reduce the concentration of available metals in the soil over time. Also, compost at 8 t/ha and 12 t/ha had a BCF of 0.8 and 0.6 respectively for Ni and BCF values less than 1 were found in Cp8 t/ha, Cp12 t/ha, Bio14 t/ha, and Bio21 t/ha with the values 0.5, 0.3, 0.9 and 0.8 for Co. It can be deduced that compost and biochar enhanced the immobilization of Ni and Co in the sesame plant. Sesame with a BCF greater than one could be a hyper-accumulator, which makes it unhealthy for human consumption when planted in metal- polluted soil.

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Effect of Different Nutrient Sources and Moisture Stress on Nutrient Uptake and Dry Matter Accumulation of Indian Spinach (*Basella alba* L.)

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Abstract

Most tropical soils are deficient in major plant nutrients. This is exacerbated by moisture stress which makes the meagre nutrients unavailable for plant uptake. This study was conducted at the screen house of Federal University of Technology Minna to determine the effect of nutrient sources and moisture stress on the performance of Indian spinach**.** The treatments were 4 nutrient sources (control, NPK 20-10-10, poultry manure, sapropel) and 4 moisture stress levels (daily, 2, 4, 6 days watering intervals) arranged in Completely Randomized Design. Results revealed that poultry manure significantly increased the dry matter of Indian spinach by 87% over the control while sapropel did not. Application of poultry manure significantly increased phosphorus uptake by 244% over the control which was similar to NPK fertilizer while sapropel increased the uptake by 85%. Plants fertilized with NPK had significantly ($p<0.05$) highest nitrogen, potassium, calcium and magnesium uptake followed by poultry manure. The least was obtained in the control plants which was statistically similar to the sapropel treated plants. Significantly highest dry matter was obtained in daily watered plants which were similar to 2 days watering interval. Similar trend was observed for all the nutrient uptake. Moisture stress imposed from 4 days watering interval significantly reduced the dry matter, N, P, K and Mg uptake in the plants. This result suggests that poultry manure will be a better alternative to chemical fertilizer in the production of Indian spinach than sapropel. Furthermore, watering at 2 days interval is adequate for the crop's optimum performance.

Introduction

Indian spinach (*Basella alba* L.) *is* a vigorous perennial climbing plant cultivated as a leafy vegetable and ornamental in tropical, subtropical and occasionally extending into temperate regions as an annual Vélez-Gavilán (2018). Common names include Malabar spinach and Ceylon spinach. It is called 'Amunututu' in Yoruba, 'Alayyahu mai ruwa' in Hausa and 'Ngbolodi' among the Igbo speaking people in Nigeria. The young stems and tips of the vegetable are used in cooking and making salad. The leaves and stem are rich in vitamin A and C, potassium, manganese, calcium, magnesium, copper, iron and numerous B-complex nutrients such as folate, pyridoxine and riboflavin (Grubben and Denton, 2004). Indian spinach has been reported for use in the treatment of numerous sicknesses like loose bowels, iron deficiency, ulcer, fever, hormonal imbalance, constipation, inflammation, wound and neutralize poison due to its restorative properties (Kumar *et al*., 2013). They are rich in various industrially important chemicals such as acacetin, anthraquinone, basellasaponins A, B, C and D, betacyanin, ferulic acid (Kumar *et al*., 2013).

Plate 1: Indian Spinach (*Basella alba*) plant

Plant growth and productivity is a function of environmental factors among which the most important are soil nutrient and moisture. Almost every process in the plant system is affected by water. It plays significant role in homeostasis maintenance and cell composition formation. Lisar *et al*. (2012) reported that 80-90% of the biomass of non-woody plants comprise of water and it is the central molecule in all physiological processes of plants. It is the major medium for transporting metabolites and nutrients. Water stress is primarily caused by the water deficit i.e. drought or high soil salinity. Plants experience water stress either when the water supply to their roots becomes limiting or when the transpiration rate becomes intense. Water stress in plants reduces the plant-cell's water potential and turgor, which elevate the solutes' concentrations in the cytosol and extracellular matrices. As a result, cell enlargement decreases leading to growth inhibition and reproductive failure. This is followed by accumulation of abscisic acid (ABA) and compatible osmolytes like proline, which cause wilting (Lisar *et al*., 2012). Furthermore, water deficit reduces the availability and uptake of nutrients by plant roots thereby limiting crop growth and development. Climate change has negatively impacted on the availability of water; there is increasing scarcity of irrigation water (Zhang *et al*., 2014). It is therefore important to practice climate smart agriculture in which just the adequate amount of water is made available to the plant. Adoption of a suitable irrigation water management practice is necessary to improve crop productivity and reduce cost of production.

A constant and sustained supply of plant nutrients is important for the enhancement of global crop production in terms of quality and quantity to meet the food demand of the growing population. Successful commercial vegetable production cannot be achieved without fertilizer application in the tropics as tropical soils are deficient in major nutrient element (Kostov, 2016). Application of inorganic or organic fertilizers are the major ways through which plant nutrient is been supplied to maintain productivity but the use of inorganic fertilizers is not sustainable due to its deleterious effects on the environment and human health. It is therefore important to test other alternative organic sources of plant nutrients which are more environmentally friendly. Use of animal manure has been reported to improve the productivity of crop among which poultry manure has been reported to be effective by many researchers. However, considering the bulkiness and messy nature of animal dung, it is important to test other organic alternative. Sapropels are subaqueous layers formed at the bottom of nutrient rich water under anaerobic condition (Ismail-Meyer *et al*., 2018). It is a clean and ecologically friendly natural material obtained from remains of plankton, water plants and other water dwelling organism used as biofertilizers and in soil conditioning (Marunga *et al*., 2020). This study therefore aimed at determining the effect of water stress and suitability of poultry manure and sapropel as replacement for inorganic fertilizer for Indian spinach production.

Materials and Methods

The experiment was conducted between August and October, 2019 at the screen house of Federal University of Technology, Minna, Nigeria. It was a 4 x 4 factorial experiment comprising 4 water stress levels (daily watering, 2, 4 and 6 days watering intervals) and 4 nutrient sources (control, NPK 20-10-10, poultry manure and sapropel biofertilizer). These were arranged in Completely Randomized Design (CRD) with four replicates. Four seeds were sown per pot filled with 3.5 kg of top soil at a depth of 5 cm. The seedlings were thinned to two stands per pot at two weeks after sowing. The water stress schedule was introduced at 3 weeks after sowing following the treatments. At each watering day, the soil was watered to field capacity with 40 cl of water per pot. NPK 20-10-10, sapropel and poultry manure were applied at the rate of 625 kg ha^{-1}, 1580 kg ha^{-1} and 3 ton ha^{-1} respectively according to the recommendations of Pujari (2017), Salami and Babajide (2015). The sapropel used (Emerald fertilizer sapropel) contained 7.91% N, 17.37 mg/kg phosphate and 7.76 mg/kg potassium.

The plants were harvested at nine weeks after sowing. The dry matter was obtained by oven drying the harvested plants at 70°C until constant weight was obtained. The total nitrogen present in the plant tissues was determined using micro Kjeldahl method as described by Okalebo (2002). The phosphorous available in the plant tissues was determined using the Bray 2 method as described by Okalebo (2002). Potassium, calcium and magnesium were extracted with ammonium acetate solution. Potassium was read using flame photometer while exchangeable magnesium and calcium were read with atomic absorption spectrometer Okalebo (2002). The uptake of the above nutrients were determined using the equation below:

$$\frac{\%\ \text{Nutrient in plant tissue} \times \text{dry matter}}{100}$$

(Sharma *et al.*, 2012)

All data collected were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS).

Results

Effect of moisture stress on dry matter accumulation and nutrient uptake of Indian spinach

Dry matter accumulation in plants that received every day and 2 days watering intervals were similar (7788.57 and 7700 mg/kg soil respectively) and statistically higher than the plants that received 4 days and 6 days watering interval which had the least dry matter yield (6102.86 and 5862.86 mg/kg soil respectively) (Figure 1).

There was no significant difference between the N-uptake of Indian spinach that received every day, 2 days and 4 days watering interval (354.33, 366.95 and 286.18mg/kg soil respectively). The least N-uptake was observed at 6 days watering interval which was significantly lower (261.48mg/kg soil) than plants that received 2 days watering interval (Figure 2).

Phosphorus (P) uptake of the plants that received every day and 2 days watering intervals were similar (1.42 and 1.40 mg/kg soil respectively) and statistically higher than the plants that received 6 days watering interval which had the least P-uptake (1.00 mg/kg soil) (Figure 3).

There was no significant difference between the potassium (K) uptake of the plants that received every day and 2 days watering interval (3.94 and 4.08 mg/kg soil respectively). The least K-uptake was observed at 4 days and 6 days watering interval which were statistically similar (2.48 and 2.62 mg/kg soil respectively) (Figure 3).

There was no significant difference between the magnesium (Mg) uptake of plants that received every day, 2 days and 4 days watering interval (1.10 and 1.16 mg/kg soil respectively). The least Mg-uptake was observed at 6 days watering interval (0.71 mg/kg soil respectively) which was significantly lower than plants that received 2 days watering interval. Similar trend was observed for calcium (ca) uptake (Figure 3).

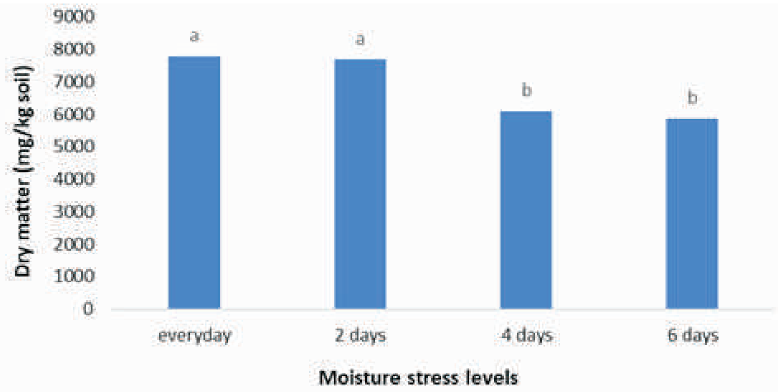

Figure 1: Dry matter of Indian spinach as affected by moisture stress

Means with the same letters are not significantly different at $p \leq 0.5$ using LSD

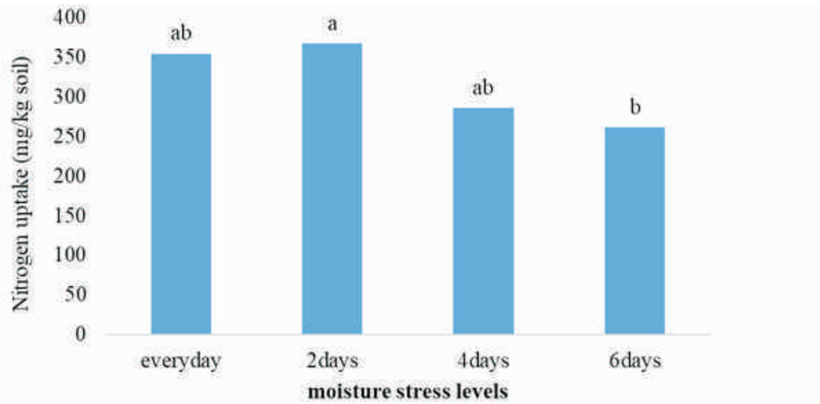

Figure 2: Nitrogen uptake of Indian spinach as affected by moisture stress.

Means with the same letters are not significantly different at $p \leq 0.5$ using LSD

Effect of nutrient sources on dry matter accumulation and nutrient uptake of Indian spinach

The plants treated with N.P.K fertilizer had the significantly highest dry matter yield (10365.71 mg/kg soil) followed by poultry manure (8188.57 mg/kg soil). The least dry matter yield was observed in control plants (4651.43 mg/kg soil) which were however statistically similar to sapropel treated plants (4902.86 mg/kg soil respectively) (Figure 4).

Plants treated with N.P.K fertilizer had significantly highest N-uptake (523.40 mg/kg soil), followed by plants that received poultry manure (343.37 mg/kg soil). The least N-uptake was observed in control plants 176.50 mg/kg soil similar to sapropel treated plants (225.67 mg/kg soil) (Figure 5).

The plants treated with poultry manure had significantly highest P-uptake (1.79 mg/kg soil) which was statistically similar to NPK fertilizer (1.63 mg/kg soil). This was followed by plants that received sapropel (0.96 mg/kg soil). The least P-uptake was observed in control plants (0.52 mg/kg soil) (Figure 6). Plants treated with N.P.K fertilizer had significantly highest K-uptake (4.89 mg/kg soil), followed by plants that received poultry manure (3.92 mg/kg soil). The least K-uptake was observed in control plants (1.87 mg/kg soil) statistically similar to sapropel treated plants (2.46 mg/kg soil) (Figure 6).

Plants treated with N.P.K fertilizer had significantly highest Mg-uptake (1.49 mg/kg soil), followed by poultry manure (0.90 mg/kg soil). The least Mg-uptake was observed in sapropel treated plants (0.59 mg/kg soil) similar to the control plants (Figure 6).

Plants treated with N.P.K fertilizer had significantly highest Ca-uptake (4.47 mg/kg soil), followed by poultry manure treated plants (3.14 mg/kg soil). The least Ca-uptake was observed in control plants (2.38 mg/kg soil). This was however statistically similar to the value obtained in sapropel treated plants (2.44 mg/kg soil) (Figure 6).

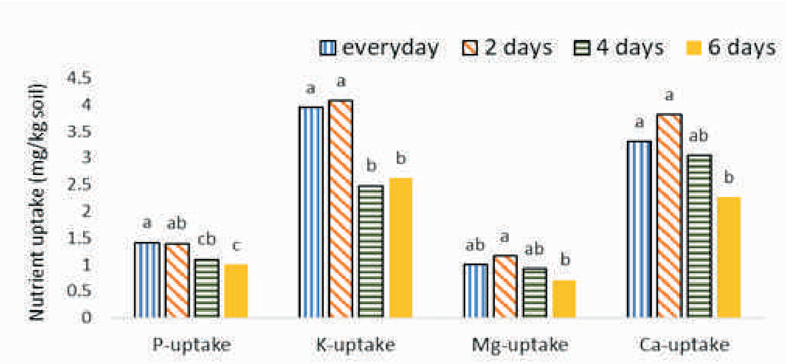

Figure 3. Nutrient uptake of Indian spinach as affected by moisture stress

Means with the same letters are not significantly different at p≤0.5 using LSD

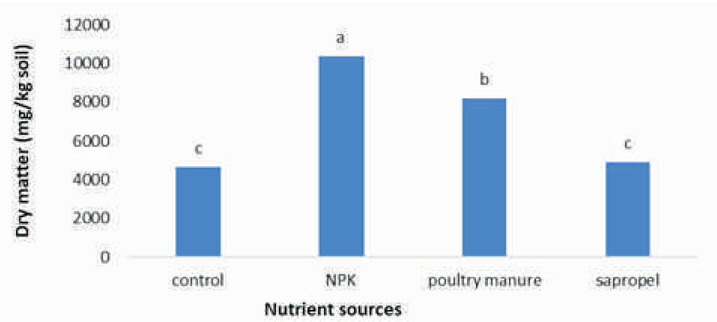

Figure 4: Dry matter of Indian spinach as affected by nutrient sources

Means with the same letters are not significantly different at p≤0.5 using LSD

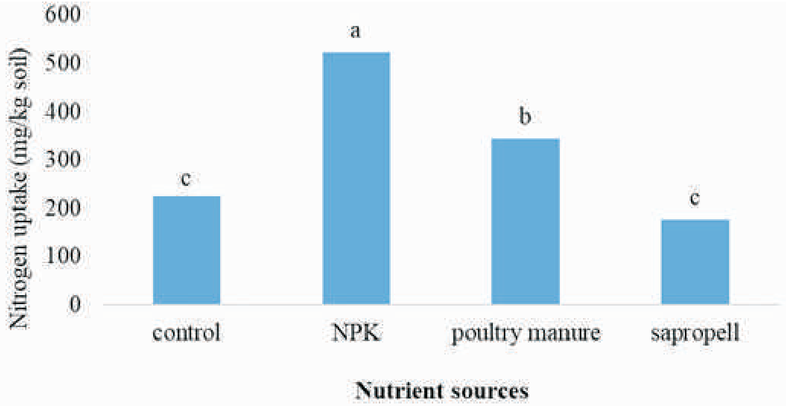

Figure 5: Nitrogen uptake of Indian spinach as affected by different nutrient sources.

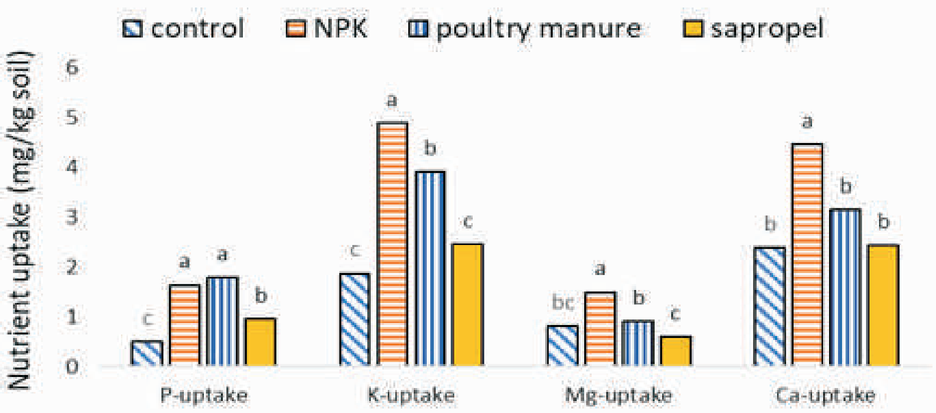

Figure 6. Nutrient uptake of Indian spinach as affected by nutrient sources

Discussion

The significant reduction observed in dry matter accumulation in 4 and 6 days watered plants compared to daily and 2 days watered plant suggests that moisture stress sets in after 2 days watering interval. Reduction in growth might have been responsible for reduction of dry matter recorded in the water stressed plants. Water is important for all physiological processes leading to growth in plants; among which photosynthesis is the most important for dry matter accumulation. Zhu *et al*. (2020) observed that moisture stress causes change in the photosynthetic properties of plants. When plants sense moisture deficit, they close their stomata to reduce loss of moisture through evapotranspiration. This is mainly controlled by chemical signals such as abscisic acid (ABA) production in dehydrating roots (Pirasteh-Anoshe, 2016). Stomata closure will in turn prevent inflow of carbon dioxide into the leaf mesophyll cell for carbon fixation in the dark reaction of photosynthesis. Water stress affects various physiological processes associated with growth, development and yield. Water deficit disturbs normal turgor pressure, and the loss of cell turgidity may stop cell enlargement leading to reduced plant growth (Srivalli *et al*., 2003).

The significantly higher nutrient uptake obtained in daily and 2 days watering compared to 4 and 6 days interval could be attributed to better water availability in the soil. Soil moisture is the most important factor that determine nutrient uptake in plants. Plants take up nutrients as ions; for nutrient uptake to occur in plants, the nutrient ion must be in position adjacent to the root. The nutrient ion is positioned through mass flow, diffusion or root interception. Mass flow and diffusion are responsible for the majority of nutrient uptake and are both dependent upon the presence of water in contact with the soil surface and the root. Smethurst (2004) similarly reported that the rate of uptake depends primarily on the concentration in the soil solution immediately adjacent to the root but the concentrations of nutrients at root surfaces depend strongly on soil water content.

The significantly higher dry matter accumulation and nutrient uptake observed in NPK and poultry manure treated than control plants confirms the importance of nutrient amendments in enhancing not only the growth and yield of crops but also the nutritional quality. Though poultry manure significantly improved the dry matter accumulation and nutrients uptake over the control in this study, but not as much as plants treated with NPK fertilizer. This may be attributed to higher concentration of N, P and K in the NPK fertilizer than poultry manure. Furthermore, nutrients in chemical fertilizers are readily available for plant growth than organic fertilizer which releases their nutrients slowly. Most of the nitrogen in poultry manure is in the organic form and need time to mineralize before becoming available to plant. However, the full benefit of organic manure may not be reaped in just one season of cropping. Organic manure improves soil structure over time increasing the soil's ability to retain nutrients. Furthermore, they are biodegradable and environmentally friendly preventing toxins, salts, and chemicals build up in the soil unlike inorganic fertilizer whose persistent use destroys soil reaction and impedes the activities of soil microorganisms thereby making the soil acidic and toxic (Okoroafo *et al*., 2013).

In this study, sapropel did not significantly increase dry matter accumulation and nutrient uptake. The nutrients in the sapropel fertilizer may not also be readily available for plant immediate use. Agafonoya *et al.* (2015) reported that sapropel's positive effect is manifested in subsequent years of crop cultivation. This may suggest that when using sapropel as the nutrient source, little quantity of chemical fertilizer need to be added to the soil especially in the first season for short-lived crops. At the long run, it may cut down on the quantity of chemical fertilizer used.

Conclusion

NPK fertilized crop had the best performance in this study. However, for organic production of Indian spinach, poultry manure will serve as a better alternative to NPK fertilizer in the production of the crop than sapropel. Furthermore, watering at 2 days interval is adequate for optimum productivity and quality of the crop.

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Possibilités de Developpement de L'apiculture Biologique au Regard des Pratiques Apicoles dans la Region Centrale du Togo

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Résumé

La région Centrale du Togo présente de nombreuses potentialités de production apicole du fait de ses aires protégées qui occupent environ 20% de sa superficie totale. La production apicole togolaise est en pleinedéveloppement et le pays vient d'obtenir l'autorisation d'exporter le miel vers l'Europe, qui est le second importateur mondial de miel biologique. L'objectif de cette étude est d'analyser les possibilités de développement del'apiculture biologique, inexistante dans la région Centrale du Togo. La méthodologie utilisée pour la collecte de données se résume à la documentation et une enquêtesocio-économique par questionnaire. Il ressort des analyses que le développement de l'apiculture biologique est possible dans la région Centrale compte tenu des forces(une majorité d'apiculteurs jeunes et pratiquant ce métier depuis plus de 5 anset la présence d'aires protégées) et d'importantes opportunités qui sont en sa faveur (apiculture parmi les filières porteuses pour les jeunes togolais et soutenue par le gouvernement, accessibilité au marché européen).Quelques faiblesses (en moyenne 5 ruches par apiculteur et le coût très élevé de la certification biologique pour les petits apiculteurs)et menaces identifiées (utilisation incontrôlée et quasi généralisée de pesticides en agriculture) sont surmontables avec plus d'engagements du gouvernement en faveur de la filière, plus de soutien aux producteurs pour faciliter l'accès aux financements et aux actifs de production, l'adoption des pratiques agroécologiques et l'accélération de la structuration des acteurs.

Abstract

The Central region of Togo has a lot of potential for beekeeping production because of its protected areas, which cover about 20% of its total surface area. Togo's beekeeping production is in full development and the country has just obtained the authorization to export honey to Europe, which is the world's second largest importer of organic honey. The objective of this study is to analyse the possibilities to develop organic beekeeping, which does not exist in the Central region of Togo. The methodology used for the data collection is based on documentation and a socio-economic survey by questionnaire. The analyses show that the development of organic beekeeping is possible in the Central region given the strengths (a majority of young beekeepers who have been practising this activity for more than 5 years and the presence of protected forest)and important opportunities that are in its favour (beekeeping among the promising sectors for young Togolese and supported by the government, accessibility to the

European market). Some weaknesses (an average of 5 hives per beekeeper and the very high cost of organic certification for small beekeepers) and threats identified (uncontrolled and almost widespread use of pesticides in agriculture) can be overcome with more government commitment to the sector, more support for producers to facilitate access to finance and production assets, the adoption of agro-ecological practices and the acceleration of the structuring of actors.

Keywords:
Honey, organic beekeeping, Central Region, Togo, protected areas.

Introduction

L'apiculture, activité pratiquée partout au Togo, constitue une source importante de revenues pour les populations, surtout rurales. La production apicole nationale était estimée à 37 727 litres en 2018 et 59 833,8 litres en 2019 soit une hausse de 58,6%, ce qui dénote de l'ampleur que prend ce secteur au Togo (Gouvernement du Togo, 2021).

La région Centrale avecses aires protégées (Parc National de Fazao Malfakassa etReserve de Faune d'Abdoulaye), estune zone à fort potentiel apicole.Elle produit la plus grande quantité de miel devant la région des Savanes(Gouvernement du Togo, 2021). L'apiculture y est une activité émergente et participe à la protection de l'environnement, à la préservation de la biodiversité des aires protégées et à la lutte contre la pauvreté des populations installées autour de ces espaces. Dans le temps, la pratique apicole dominanteconsistait à la chasse aux abeilles dans les forêts avec des conséquences telles que la fuite des colonies et les feux de brousse dévastateurs.Grâce aux différentes interventions des partenaires au développementà partir des années 70, l'activité apicole a été dynamiséeavec la promotiondes pratiques modernes telles que l'utilisation de ruches fabriquées.

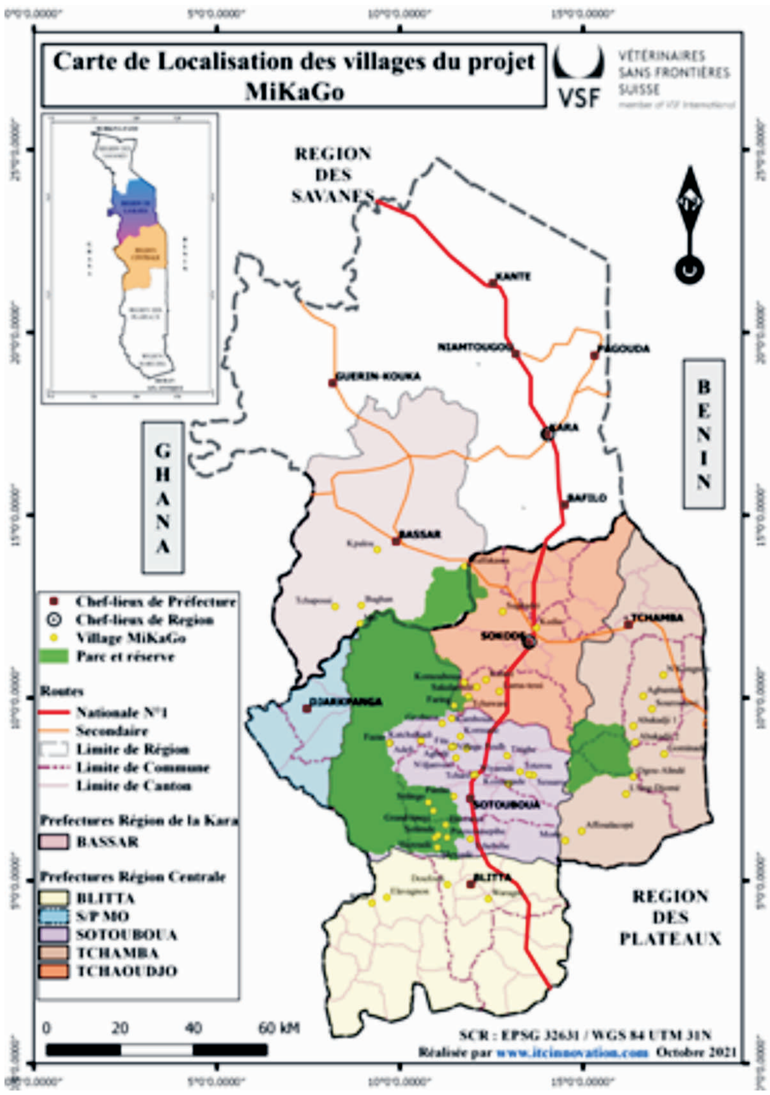
L'activité apicole constitue une véritable source de revenus pour les producteurs de la région Centrale ; ces revenus contribuent significativement à leurs dépenses vitales(Sokemawu, 2016). En plus de la demande exigeante (en qualité) des produits de ruche sur le marché national, le Togo vient d'obtenir l'autorisation pour exporter son miel vers les pays européens (Afrique Agriculture, 2021). Sachant que l'Union Européenne est le deuxième importateur mondial du miel biologique après les Etats-Unis (Interbioccitanie, 2020), les apiculteurs togolaisdevraient s'attendre à une demandecroissante de ce produit dans les années à venir. Mais sont – ils prêts à produire du miel biologique dans les conditions actuelles ?

L'objectif général de cette étude est de faire une analyse des possibilités de développement de l'apiculture biologique dans la région Centrale du Togo au regard des pratiques apicoles actuelles.

Methodologie

Zone d'étude

L'étude a été conduite dans la région Centrale du Togo (carte 1). Elle couvre une superficie d'environ 13 500 km^2 dont plus de 20% d'aires protégées(environ 2 700 km²). Le Parc National du Fazao-Malfakassa (PNFM) et laReserve de Faune d'Abdoulaye (RFA) constituent la plus importante zone de production apicole.



Carte n°1. Localisation de la zone d'étude

L'espace d'étude est caractérisé sur le plan physique et naturel par un relief de plateaux et de plaines propices au développement d'une gamme variée d'arbres mellifères (anacardes, tecks, orangers, manguiers, eucalyptus, néré, karité, etc.) sur des sols diversifiés. Du point de vue climatique, elle appartient à la zone tropicale semi-humide et fait partie intégrante de la zone soudano-guinéenne caractérisée par deux saisons nettement distinctes à savoir une saison pluvieuse qui dure 6 mois (mai à octobre) et une saison sèche qui s'étend sur 6 mois (novembre à avril). La température varie entre 20°C et 32°C avec les minima enregistrés pendant la période d'harmattan et les maxima relevés pendant les mois de février-mars (Samarou, 2011). Ces paramètres climatiques, combinés aux éléments physiques favorisent le développement du couvert végétal, lieu de prolifération des abeilles. La longueur de la saison sèche est très bénéfique à la production du miel de qualité par les abeilles. La saison pluvieuse est celle de la pose des ruches par les apiculteurs, de leur colonisation par les abeilles et du prélèvement du nectar des fleurs de plantes par les abeilles pour la production du miel.

Collecte de données

Afin d'obtenir les informations sur les pratiques apicoles actuelles dans la région d'étude, la méthode utilisée a consisté à une enquête sociologique basée sur le questionnaire. Pour cela, l'outil d'enquête Kobo Toolbox a été mis à profit. Les observations ont été menées danscinq préfectures ciblées. Quatre (04) différentes préfectures de la régionCentrale du Togo (Blitta, Sotouboua, Tchaoudjo et Tchamba) et la préfecture de Bassar située au nord de ladite région. Ainsi, un échantillon de 160 apiculteurs a été ciblé, répartis dans 32 villages.

Le choix aléatoire a été associé au choix raisonné dans la sélection des apiculteurs à enquêter, ceci afin d'avoir une meilleure représentativité de la diversité de la zone d'étude.

Traitement de données

Les analyses réalisées dans cette étude se sont basées sur les données collectées sur le terrain durant la période du 21 Avril au 04 Mai 2021, portant sur les réponses d'un nombre limité d'apiculteurs. Parmi les 160 répondants, 4 fiches de réponse ont été annulées car n'étant pas concluantes. 156 fiches ont été validées et donc ont constitué la base d'analyse et d'interprétation.

Les informations obtenues de l'administration des questionnaires ont été dépouillées et analysées aux logiciels SPSS et EXCEL.

Resultats et Discussions

Caractéristiques socio – démographiques des apiculteurs

Les apiculteurs dans la région Centrale sont majoritairement des hommes (97%). Une observation similaire (94,29%) a été faite par AHOUANDJINOUet *al*(2016) au Nord-ouest du Benin. Les moins de 50 ansreprésentent 80%, ce qui équivaut à une population jeune (photo 1). Ce tauxest proche (91%) de celui retrouvépar AHOUANDJINOUet *al*(2016) et plus élevé que celui deSokemawu (2016) qui avait trouvé un taux d'apiculteurs âgés de moins de 50 ans de 58,62% dans la même zone.

Plus de la moitié (55,4 %) des apiculteurs a atteint un niveau d'étude secondaire et 33,1% ont fait le primaire.

L'âge adulte et le niveau de scolarisation des apiculteurs dans la zone d'étude est favorable à un apprentissage avec succès des techniques apicoles améliorées, surtout si la technique de formation est participative, cas des champs école de producteurs (CEP) promus par la FAO. Aussi la diffusion des techniques apicolespeut se faire en français (langue de la plupart des manuels d'apprentissage) avec l'assurance que les bénéficiaires les appréhendent aisément.

De plus, ce niveau de scolarisation acceptable est favorable à la satisfaction de l'exigence de tenu de registre dans le cadre de l'apiculture biologique. En effet, l'apiculture bio exige que l'apiculteur tienne à jour un registre des emplacements de ruches, des traitements, des flux des marchandises, de la nourriture d'abeilles et des informations (date, quantité, nombre de ruche) sur la récolte du miel (FiBL, 2017 et MEER et *al*, 2019)

Photos 1. Des apiculteurs en activité (installation de ruche, miel et cire)

Source : VSF Suisse, 2021

Caractéristiques socio – économiques des apiculteurs

L'agriculture est la principale activité pratiquée par la majorité des apiculteurs (90%) dans la zone d'étude. Il faut noter que l'agriculture pratiquée dans ces zones est très utilisatrice de pesticides et herbicides (KARA-PEKETI et *al*., 2009). Ils pratiquent l'apiculture et l'élevage comme activité secondaire. Ce second rang attribué à l'apiculture a aussi été constaté par Sokewawu (2016) mais pour une proportion d'apiculteurs plus importante (63,99%).

Selon les apiculteurs (86,6%), l'agriculture est l'activité la plus rentable. Seulement 5,7% pensent que l'apiculture est l'activité la plus rentable.

En réalité, les paysans estiment la rentabilité d'une activité à partir des revenus qu'ils en perçoivent ; très peu arrivent à faire une analyse économique pour estimer les revenus nets. L'étude de Sokémawu (2016) a montré que plus de 72% de ceux qui pratiquent l'apicultures'estiment plus heureux avec les revenus apicoles par rapport aux revenus nets tirés de la production agricole (maïs, ignames, niébé, cotons).

Systèmes apicoles dans la zone d'étude

Deux systèmes de production sont rencontrés dans la région Centrale : la chasse au miel (50%) et l'apiculture moderne (48%).

Des efforts sont encore nécessaires pour réduire la pratique de chasse au miel qui est néfaste à l'environnement.

A part le miel, quelques apiculteurs (12%) récoltent la cire ; Elle est encore méconnue par une grande majorité d'entre-deux dans la zone d'étude. Mais il est attendue que sa demande croisse les prochaines années, à la suite de l'installation au Togo d'un important acheteur américain ; cette firme qui ambitionne de développer une filière d'approvisionnement durable de cire d'abeille en Afrique de l'Ouest, a signé un premier contrat d'achat de 3,5 tonnes de cire en 2019 avec la plateforme apicole togolaise (Commodafrica, 2019).

L'expérience dans l'apiculture et niveau de formation

En moyenne, les apiculteurs de la zone du projet ont démarré l'apiculture depuis plus de 5 ans déjà. Cette ancienneté dans l'activité est un atout pour son développement. Le fort engouement dans l'apiculture constaté entre 2015 et 2020 dans la région Centrale est le fait de la mise en œuvre des récents projets du gouvernement dont l'important Programme d'Appui au Secteur Agricole (PASA) financé par la Banque Mondiale et ceux des partenaires au développement dont VSF-Suisse, avec des appuis apicoles.

Malgré cet engouement au développement de l'apiculture, 70% des apiculteurs enquêtés n'ont pas suivi de formation apicole avant de se lancer dans cette activité. Il y a donc un champ libre pour diffuser des pratiques nouvelles, notamment dans l'apiculture bio.

Types de ruches utilisés

Les ruches kenyanes sont les plus utilisées (29,30%) dans la zone d'étude. En deuxième place, viennent les ruches Dadant (28,70%) (photo 2). Peu sont les apiculteurs qui pratiquent leur activité avec les ruches Langstroth, encore peu connu des populations.

L'achat est le moyen majoritaire pouracquérir les ruches (51%). La fabrication personnelle et le don (des projets) sont respectivement rencontrés chez 17,20% et 28% d'apiculteurs.

Photos 2. Type de ruches rencontrées dans la zone du projet(kényane et Dadant)

Source : VSF Suisse, 2021

Equipement apicole

La majorité des apiculteurs enquêtés (67%) n'utilise aucun équipement dans leurs activités apicoles. L'enfumoir, la vareuse et les gants sont les outils les plus retrouvés respectivement chez 28,7%, 28% et 21% apiculteurs.

Il serait ainsi opportun pour ces apiculteurs d'apprendre à fabriquer et utiliser le petit matériel apicole comme l'enfumoir en respectant les exigences de l'apiculture bio (MEER *et al.*, 2019).

Spécificité des parcelles apicoles

Les parcelles dans lesquelles l'apiculture est pratiquée sont généralement de grande superficie, 3,5 hectares en moyenne. Mais il faut noter que le taux d'occupation de ces espaces reste très faible, avec en moyenne 5 ruches par exploitant. Ces espaces sont situées aux abords des aires protégées, au niveau des zones tampons ou dans des parcelles délimitées.Ces parcelles ont été acquis par don (40%), héritage (37%) ou location (21%).

Main d'œuvre apicole

La main d'œuvre est essentiellement familiale dans les activités apicoles (96%) ; ce qui montre que les exploitations sont encore de taille faible à moyenne et ne nécessitent pas de faire recours à une main d'œuvre extérieure et rémunérée.

Niveau d'organisation des apiculteurs

Plus de la moitié (54%) des apiculteurs sont membres d'un groupement apicole, mais seulement 32% des groupements ont entamé le processus d'enregistrement. Les démarches d'organisation des coopératives apicoles sont assez récentes au Togo. Le gouvernement a dénombré au total 85 sociétés coopératives simplifiées (SCOOPS) enregistrées et membres des unions apicoles préfectorales. Les acteurs des différents maillons de la filière apicole se sont organisés les 27 et 28 novembre 2019 en interprofession dénommée « Conseil Interprofessionnel de la Filière Apicole (CIFAP) ». Ce conseil est porté par la fédération nationale des coopératives apicoles et l'association nationale des produits de la ruche (Gouvernement, 2021).

De nombreuses efforts doivent encore être fournis pour assurer le renforcement des capacités des organisations des producteurs de base afin d'assurer qu'elles fournissent des services (fourniture de matériel, collecte de miel et commercialisation, transformation) efficaces à leurs membres.

Les principales difficultés rencontrées dans l'apiculture

Plus de la moitié (55%) des apiculteurs dans la zone d'étude sont confrontés aux attaques d'ennemies de ruche (les rongeurs, les fournis, les reptiles, les chenilles et fausse teigne) et 37% ont déclaré être victimes des vols de miel dans les ruches.

Connaissances et pratiques durables en agriculture

44% des apiculteurs font recours aux pratiques durables en agriculture (réhabilitation des pâturages dégradés, agroforesterie, diversification et rotation des cultures). L'adoption de ces pratiques a sûrement été influencée par les sensibilisations réalisées depuis les années 2000 à nos jours. KOUDEGNAN et al (2015) avaient trouvé que les apiculteurs dans la zone IV du Togo plantent entre 87 et 136 arbres annuellement, soit un nombre beaucoup plus important que ceux abattus dans la même zone.

L'adoption des pratiques agroécologiques contribue à réduire l'utilisation des produits phytosanitairesautour des ruchers et est favorable au développement de l'apiculture biologique. En effet en apiculture biologique, l'utilisation des produits chimiques de synthèse est strictement interdite dans un rayon de 3 km autour d'un rucher (FiBL, 2017 et MEER et *al*, 2019).

Analyse des forces, faiblesses, opportunités et menaces pour le développement d'une apiculture biologique en région centrale au Togo

Forces

Les apiculteurs dans la région Centrale sont majoritairement jeunes (moins de 50 ans) et lettrés. Ces facteurs sont favorables à un apprentissage de nouvelles pratiques.

La plupart d'entre eux exercent l'activité depuis plus de 5 ans et s'y intéressent. Beaucoup étaient des anciens chasseurs de miel. Ils ont donc une certaine habitude de pratique de l'apiculture.

Quelques apiculteurs font recours aux pratiques d'agroécologie et de reboisement et parmi eux, il y en a qui sont déjà des producteurs de soja biologique et sont déjà bien familiarisés avec les exigences de cette filière.

La région Centrale, grâce à ses aires protégées, offre aux apiculteurs de la zone un climat idéal pour leurs activités apicoles.

Faiblesses

La production de miel bio concerne surtout les apiculteurs détenant plus de 50 ruches. Les apiculteurs de la zone d'étude n'en sont qu'à 5 ruches en moyenne mais avec un potentiel de croissance les prochaines années, vue qu'ils disposent de l'espace (3,5 ha par apiculteur).

La certification constitue en effet un surcoût en partie fixe quel que soit le nombre de colonies. Elle est donc d'autant plus difficile à rentabiliser que le nombre de colonies est faible comme ce pourrait être le cas dans la zone d'étude. Le coût de la certification est de l'ordre de 260 000 à 400 000 F CFA/an selon l'organisme certificateur (FNAB, 2017) ; ce niveau de charge est difficilement supportable par les petits apiculteurs au Togo.

L'apiculteur bio passe également plus de temps pour gérer et prendre soin de ses ruchers. En effet, l'apiculture biologique exige d'être particulièrement attentif au moindre déséquilibre ou phénomène parasitaire. Les coûts de la main d'œuvre qualifiée sont donc à considérer dans les charges surtout que les apiculteurs de la région Centrale sont principalement préoccupés par leurs activités agricoles.

Opportunités

Le gouvernement togolais est engagé dans le développement des filières de produits forestiers non ligneux dont le miel. L'apiculture est identifiée parmi les filières économiquement porteuses surtout pour les jeunes (Gouvernement du Togo, 2019). Les ministères en charge de l'agriculture, celui en charge de l'économie et celui en charge de l'environnement ont d'importants programmes en cours orientés vers le développement de cette filière. Ces initiatives sont de plus en plus soutenues par des partenaires étrangers, dans le cadre des projets en faveur de la protection de l'environnement et de lutte contre la pauvreté. Dans la région Centrale, il s'agit notamment de :

- la FAO qui appui le Ministère de l'environnement dans la mise en œuvre du projet « appui à l'élaboration du programme national de gestion durable des produit forestiers non ligneux et la mise en place des actions prioritaire au Togo » (2019 – 2023)
- L'UNESCO appui la mise en œuvre du projet « de promotion des moyens d'existence respectueux de la biodiversité dans le parc national de Fazao-Malfakassa » ;
- VSF-Suisse met en œuvre le projet « Miel d'abeilles saines et Karité des petits producteurs pour les marchés rémunérateurs et pour une meilleure Gouvernance des aires protégées des hauts plateaux du Togo (MiKaGo 2021 – 2023) » ;
- La coopération allemande finance le projet Global « Restauration de paysages forestiers et bonne gouvernance dans le secteur forestier » (Forests 4 Future) qui a un volet d'appui à l'apiculture.

Depuis quelques mois, le Togo peut désormais exporter son miel vers l'Europe ; cette nouvelle est une importante opportunitépour les apiculteurs togolais sachant que l'Union Européenne est le second importateur mondial du miel biologique après les Etats-Unis.

La présence de la grande firme américaine qui exploite la cire d'abeille au Togo depuis 2019 est une autre importante opportunité pour les apiculteurs togolais, d'autant plus que cette firme s'intéresse à la gamme biologique et est prête à acheter toute la production disponible.

Par ailleurs, l'offre pour le miel biologique est très insuffisante à la demande mondiale.

La filière commence à s'organiser avec la présence d'une interprofession et des unions préfectorales et régionales. Il existe aussi des acteurs d'appui tel que l'Institut de conseils et d'appui technique (ICAT) et des

ONG capablesd'accompagner le développement de l'apiculture biologique basé sur les manuels existants tel que le manuel « Module 10 Crops Unit 01 Beekeeping of African Organic Agriculture Training Manual » la FiBL en Suisse.

Menaces

Quelques menaces sont identifiées au développement d'une apiculture bio dans la zone d'étude:

- Les feux de brousse, les vols et renversement des ruches: les communautés peuvent prévenir ces infractions en renforcement les mécanismes de surveillance et de dénonciation ;
- la présence d'ennemiesde ruches ; le projet MiKaGo de VSF-Suisse prévoie de mener une première étude sur la situation sanitaire des abeilles afin de mieux comprendre et proposer des solutions aux apiculteurs ;
- L'utilisation incontrôlée et quasi-généralisée des produits chimiques de synthèse dans l'agriculture (KARA-PEKETI et *al*., 2009). Les sensibilisations doivent se poursuivre pour réduire ces pratiques et proposer des alternatives durables.

Conclusion et Recommandations

L'objectif de cette étude est de faire une analyse sur les possibilités de développement de l'apiculture biologique dans la région Centrale du Togo au regard des pratiques apicoles actuelles. En se basant sur les constats des pratiques apicoles actuelles, et au regard des exigences de l'apiculture biologique, l'étude montre que les facteurs tels que l'âge des apiculteurs, leur niveau d'instruction et l'expérience dans l'apiculture constituent des forces en faveur du développement de l'apiculture biologique. De même, de nombreuses opportunités se présentent à cette filière notamment une volonté affichée du Gouvernement, un nouveau marché européen, la présence d'un important acheteur de cire.

Il existe cependant quelques faiblesses (faible niveau de production avec seulement 5 ruches par producteurs, faible niveau d'organisation) et menaces (utilisation abusive de pesticides chimiques dans l'agriculture) qui peuvent être levées.

Des recommandations peuvent ainsi être formulées à l'endroit des acteurs suivants :

- Gouvernement et ses partenaires techniques et financiers: concrétiser davantage la volonté de promouvoir la filière apicole par des investissements plus accrus axés sur l'accès aux financements pour les acteurs de la filière, l'accès aux actifs de production (ruches, extracteurs), la recherche de nouveaux marchés extérieurs comme celui des Etats – Unis à travers le mécanisme AGOA.
- Faitières apicoles : développer les services pour les coopératives de base.
- Recherche et les universités : mener des études pour mieux connaitre la dynamique des colonies d'abeilles et les différentes maladies d'abeilles.
- Apiculteurs : réduire l'utilisation des produits phytosanitaires et prioriser les pratiques agricoles durables.
- Acheteurs : développer la pratique d'apiculture contractuelle.

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Effects of Organic Manure and Botanical Seed Treatment on Striga Hermonthica Control in Sorghum Bicolor

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Organic farming, Organic manure, *Parkia* pulp powder and *Striga* hermonthica control

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Abstract

Sorghum (*Sorghum bicolor* L. Moench) is a staple food source in sub-Saharan Africa. It also constitutes a basic feed component in the livestock industry. Despite its socio-economic importance, sorghum yield is seriously threatened by *Striga hermonthica* infestation. The objective of this study was to determine the impacts of organic manure and *Parkia biglobosa* pulp powder powder on *Striga hermonthica* control in sorghum. The experiment was conducted in a screen house at the Teaching and Research Farm, Federal University of Technology, Minna, Nigeria. The research was a 2×4 factorial experiment in a completely randomised design with sixteen treatments in three replications. Treatments consisted of combinations of four levels of organic manure and *Parkia biglobosa* pulp powder powder each at 0, 40, 80, and 120g/bag. Data were collected on *Striga* emergence, *Striga* height, *Sorghum* plant height, and the number of leaves per plant. The data were subjected to analysis of variance at p=0.05. The results showed that *Striga* emergence did not vary significantly throughout the sampling periods. However, the treatment used inhibited the growth of *Striga*. Organic manure at the rate of 120 g /bag resulted in the highest number of *Sorghum* plant height, leaves and dry weight. The interaction effect of *Parkia* pulp powder powder and botanical seed treatment was significant ($p<0.05$) on *Striga* emergence, plant height and sorghum dry weight. The combination of the treatments suppressed more than 75 % of *Striga hermonthica* emergence. These findings revealed that organic farming can effectively be used to combat *Striga hermonthica* in sorghum.

Effets du Fumier Organique et du Traitement des Semences Botaniques sur le Contrôle de Striga Hermonthica Dans le Sorgho Bicolor

Résumé

Le sorgho (*Sorghum bicolor* L. Moench) est une source alimentaire de base en Afrique subsaharienne. Il constitue également un composant alimentaire de base dans l'industrie de l'élevage. Malgré son importance socio-économique, le rendement du sorgho est sérieusement menacé par l'infestation de *Striga hermonthica*. L'objectif de cette étude était de déterminer les impacts de la fumure organique et de la poudre de pulpe de *Parkia biglobosa* sur le contrôle de *Striga* hermonthica dans le sorgho. L'expérience a été menée dans une serre à la ferme d'enseignement et de recherche de l'Université fédérale de technologie de Minna, au Nigeria. La recherche était une expérience factorielle 2 × 4 dans une

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conception entièrement randomisée avec seize traitements en trois répétitions. Les traitements consistaient en des combinaisons de quatre niveaux de fumier organique et de poudre de pulpe de Parkia biglobosa chacun à 0, 40, 80 et 120 g/sac. Des données ont été recueillies sur l'émergence du *Striga*, la hauteur du *Striga,* la hauteur de la plante de sorgho et le nombre de feuilles par plante. Les données ont été soumises à une analyse de variance à p=0,05. Les résultats ont montré que l'émergence de *Striga* ne variait pas de manière significative tout au long des périodes d'échantillonnage. Cependant, le traitement utilisé a inhibé la croissance de *Striga*. Le fumier organique à raison de 120 g/sac a donné le plus grand nombre de hauteur de plante de sorgho, de feuilles et de poids sec. L'effet d'interaction de la poudre de pulpe de *Parkia* et du traitement des semences botaniques était significatif (p <0.05) sur l'émergence du *Striga*, la hauteur de la plante et le poids sec du sorgho. La combinaison des traitements a supprimé plus de 75 % de l'émergence de *Striga hermonthica*. Ces résultats ont révélé que l'agriculture biologique peut être utilisée efficacement pour lutter contre *Striga hermonthica* dans le sorgho.

Mot clé :
Agriculture biologique, Fumure organique, Poudre de pulpe de Parkia et lutte contre le Striga hermonthica

Introduction

The primary centre of origin and diversity for sorghum are believed to be in sub-Saharan Africa extending from the extreme East to West Africa (Tarekegne, 2014) Sorghum is an indigenous crop of Ethiopia where a tremendous amount of variability exists in-country (Adugna, 2007). It has a diversity of both domesticated and wild relatives which revealed Ethiopia as the centre of origin and diversity (Mekibeb, 2009). The United States is the world's largest producer of sorghum followed by Mexico, Nigeria, Sudan and India, Ethiopia is the third-largest producer of sorghum and one of the major sorghum growing countries in Africa next to Sudan and Nigeria (FAO, 2019). The crop is the fifth most important grain crop globally after maize, wheat, rice, and barley (FAO, 2015). It is the main staple food crop for more than 500 million people in Africa, Asia and Latin America particularly in semi-arid tropical regions where drought is the major limitation to food production. According to FAO (2017), Africa is the world's regional leader in the total production of sorghum. *Striga* species of the Orobanchaceae family are obligate root parasites that infest staple crops in sub-Saharan Africa, the Middle East, and parts of Asia (Parker, 2012). The *Striga*, particularly *S. hermonthica* has become a major threat to food security, exacerbating hunger, and poverty in many African countries (Khan *et al*., 2014). *Striga* is affecting the lives of more than 300 million people in Africa and causing enormous yield losses with a value ranging from US$7 - 10 billion annually (Rodenburg *et al*., 2010). Ejeta (2007) estimated that *Striga* affected 100 million hectares in cereal fields in Africa. Globally, nearly one million hectares of sorghum fields have been reported to be infested with *Striga*, resulting in yield losses ranging from 20 to 80 % (Hearne 2009).

Several control practices have been recommended for reducing *Striga* infestation. These include the use of resistant varieties, cultural practices, and chemical control methods (Hearne 2009). Research on the identification of control measures for *Striga hermonthica* in Africa has been conducted for the last seven decades and is still ongoing. Various control methods (e.g. land preparation, hand-pulling, hoe-weeding, trap cropping) have been tried out singly or in combination over the years with no conclusive and consistent results for the peasant farmers. This could partly be attributed to the huge amounts of seeds that accumulate over time in the seed bank (Oswald, 2004). Other methods are crop rotation, and injection of ethylene gas (Radi, 2007). The use of natural products could also inhibit the germination of *Striga* seeds to deplete the *Striga* seed bank in the soil (Yonli *et al*., 2010). Debrah *et al*. (1998) reported that *Striga* abundance is favoured by continuous cropping and low soil fertility, and hence does not do well on soils with high organic matter content. Organic manure is a complex mixture of living, dead and decomposed materials which include naturally occurring organic materials (e.g. cow dung, compost and guano). Most of the organic manure is derived from decomposing plant tissue. Organic manure contains three primary macronutrients: nitrogen (N), phosphorus (P), and potassium (K) and three secondary macronutrients: calcium (Ca), sulphur (S) and magnesium (Mg). N-fertilizer has been reported to delay *Striga* emergence, promote high sorghum yield and reduces *Striga* damage in the guinea savannah ecological zones (Sule *et al*., 2008). *Parkia biglobosa* pulp powder from the tree has been discovered to have pesticide effects in several studies. For instance, screenhouse evaluation of *Parkia biglobosa* and *Azadirachta indica* (neem tree) has been reported to be effective in inhibiting *Striga hermonthica* seed germination and subsequently reduce *Striga* emergence (Marley *et al*., 2004; Syngeta, 2004). Therefore, this study investigated the effects of organic manure and botanical seed treatment on *Striga hermonthica* control in sorghum farmland.

Materials and Methods

Study Location

The experiment was conducted under the screenhouse conditions at the Federal University of Technology, Minna, Niger State, northern Nigeria, between June and October 2013. The Federal University of Technology Minna is located on latitude 90 37'N and longitude 6 32'E with an annual mean rainfall of 1300 mm and a mean monthly minimum and maximum temperature distribution value of 22.7 °C and 34.2 °C, respectively.

Treatments and Experimental Design

The treatments comprised four levels (0, 40, 80 and 120 g) of organic manure and four levels (0, 40, 80 and 120 g) of *Parkia* pulp powder combined factorially to give sixteen treatment combinations. The treatments were arranged in a Completely Randomised Design (CRD) with three replications.

Source of *Striga* Seed, *Striga*-resistant Sorghum seed, Cattle dung and *Parkia* Pulp powder

Parkia fruits were collected from Bosso town in Minna and pounded in a mortar. Sorghum-resistant sorghum seeds were obtained from a reputable Agrochemical Seed Store in Minna. Dry cattle dung was collected from the Federal University of Technology, Animal Production Department Research Farm Minna. The pulp powder was then sieved with a 2-mm sieve. *Striga* seeds were obtained from National Cereal Research Institute (NCRI) Badeggi, Bida, Niger State.

Sowing and crop Management

Plastic pots were filled with 5 kg of heat-sterilized topsoil mixed with cattle dung. Planting was done on 29th June 2013 with sorghum seeds treated with *Parkia* pulp powder. Four seeds were sown per bag and later infested with 15 g *Striga hermonthica* seeds. The sorghum seedlings were thinned to two plants per bag two weeks after sowing. The plants were irrigated at three-day intervals to provide adequate moisture for plant growth and *Striga* emergence.

Data Collection and Analysis

Data were collected on *Striga* emergence and height at 4 and 12 weeks after sowing (WAS). sorghum plant height and the number of leaves per plant at 4, 6, and 8. The data collected were subjected to analysis of variance (ANOVA) using the computer software SPSS. Means were separated using Duncan's Multiple Range Test (DMRT) at p=0.05.

Results and Discussion

Effects of organic manure and *Parkia* pulp powder on *Striga* emergence and plant height

The effect of organic manure and botanical seed treatment resulted in significant ($p<0.05$) differences in *Striga* emergence (Table 1). *Striga* emergence varied between 0.3 and 3 shoots at 4 WAS. The combined application of 120 g organic manure and 120 g *Parkia* pulp powder enhanced the lowest *Striga* shoot emergence, whereas the highest *Striga* emergence was observed when in the absence of organic manure and *Parkia* pulp powder. Interestingly, a combination of 120 g organic manure and 40 g *Parkia* pulp powder, as well as the use of 120 g organic manure and 80 g *Parkia* pulp powder also resulted in low *Striga* emergence (0.7 shoots). At 12 WAS, a slightly similar trend was encountered, as the use of 120 g organic manure and 120 g *Parkia* pulp powder resulted in the lowest (2.3 shoots) *Striga* emergence. However, the highest *Striga* emergence of 4 shoots per pot was encountered in the absence of organic manure and *Parkia* pulp powder, as well in the application of *Parkia* pulp powder alone at 40 g, 80 and 120 g (Table 1). The lowest *Striga* emergence observed when 120 g organic manure was combined with 120 g *Parkia* pulp powder could be attributed to the high level of nitrogen from the applied organic manure, which eventually reduce *Striga* attack by increasing crop tolerance. This is consistent with the findings of Kureh *et al*. (2008) who reported that N-fertilizer delayed *Striga* emergence and promoted high *Sorghum* yield.

Effects of organic manure and *Parkia* pulp powder on *Striga* plant height

At 4 WAS, the pots without organic manure and *Parkia pulp powder* (0 g organic manure + 0 g *Parkia* pulp powder), and those treated with 0 g organic manure + 40 g *Parkia* pulp powder produced the tallest *Striga* plant height of 7.3 cm each (Table 1). Although a combination of 120 g of organic manure and 80 g of *Parkia* pulp powder resulted in the shortest *Striga* plant height (2.3 cm), the value (2.7 cm)obtained was not significantly ($p>0.05$) different when 120 g of organic manure was combined with 120 g of *Parkia* pulp powder. However, at 12 WAS, the overriding efficacy of combined application of 120 g organic manure and 120 g *Parkia* pulp powder was evident as the pots so treated had the shortest *Striga* plant height (7.7 cm). This was followed by the mean height (8.3 cm) occasioned by the combined application of 120 g organic manure and 40 g *Parkia* pulp powder, as well mean plant height (8.3 cm). when 120 g of organic manure was combined with 80 g *Parkia* pulp powder. On the other hand, the use of 40 g *Parkia* pulp powder alone resulted in the highest *Striga* plant height (14.3 cm) (Table 1). These observations clearly revealed the effectiveness of a high rate of organic manure and *Parkia* pulp powder for *Striga* control. Again, the desirable performance of both treatments was due to the synergy between the inhibitory effect of high nitrogen rate and the detrimental impact of *Parkia* pulp powder on *Striga* growth (Table 1). Again, the excellent performance of a combined application of a high rate of organic manure with *Parkia* pulp powder was due to the improved soil nutrient and unfavourable germination and growth environment for the *Striga* plants.

Effects of Organic manure and *Parkia* pulp powder on *Sorghum* plant height

The applied treatments resulted in significant height differences among the *Sorghum* plants at the various times of assessment. At 4 WAS, a combination of 120 g organic manure and 40 g *Parkia* pulp powder as well as combined application of 120 g organic manure and 120 g *Parkia* pulp powder resulted in the tallest plants (29.7 cm) (Table 2). Nevertheless, the mean height observed was statistically similar to the height recorded 29.3 cm when only 120 g organic manure was applied, and when 120 g organic manure was combined with 80 g *Parkia* pulp powder. Conversely, the plants without organic manure and *Parkia* pulp powder treatments produced the shortest plants (20 cm). In spite of this, the mean height observed was comparable to the mean height of the plants in which only *Parkia* pulp powder was used either at 40 g (20.7 cm), 80 g (20.3 cm), and 120 g (20.3 cm). Although a combination of 120 g organic manure and 80 g *Parkia* pulp powder produced the tallest (53.3 cm) plants at 6 WAS, the mean height observed was not significantly different from the plants treated either with 120 g organic manure alone (53 cm), a combination of 120 g organic manure and 40 g *Parkia* pulp powder (52.7 cm), or 120 g organic manure and 120 g *Parkia* pulp powder (52.7 cm). On the other hand, the shortest (40.3 cm) height was observed in the absence of organic manure and *Parkia* pulp powder, just as in the use of 120 g *Parkia* pulp powder alone. Next were the plants in which only *Parkia* pulp powder was applied either at 40 or 80 g, resulting in a mean height of 41 cm each. At 8 WAS, the trend in *Sorghum* plant height was as observed at 6 WAS (Table 2). These findings are in tandem with the observations reported in Kureh *et al*. (2002).

Effects of organic manure and *Parkia* pulp powder on *Sorghum* dry matter

The result showed that organic manure and seed treatment with *Parkia* pulp powder exerted significant differences in the dry matter of *Sorghum* (Table 2). The highest (5 g/plant) sorghum dry matter was recorded when 120 g organic manure was combined with 120 g *Parkia* pulp powder which was at par with 120 g of organic manure combined with 40 g *Parkia* pulp powder but statistically similar to the dry matter obtained (4.8 g/plant) when 120 g of organic manure was combined with 80 g *Parkia* pulp powder. The highest sorghum dry matter observed could be attributed to the level of nitrogen which helped in delaying *Striga* emergence and reducing attack on the plant hence promoting *Sorghum* yield and reduction in *Striga* damage. This finding is in agreement with Kurch *et al*. (2002) who reported that nitrogen fertilizer delayed *Striga* emergence, promoted high *Sorghum* and maize yield as well as reduced *Striga* damage in the guinea savannah ecological zones.

Table 1: Effect of organic manure and *Parkia* pulp powder on *Striga* emergence and plant height

Treatment	***Striga* emergence (no.)**		***Striga* plant height (cm)**	
	4 WAS	**12 WAS**	**4 WAS**	**12 WAS**
0 g organic manure + 0 g *Parkia* pulp powder	3.0^{a}	4.0^{a}	7.3^{a}	13.0^{a}
0 g organic manure + 40 g *Parkia* pulp powder	2.7^{a}	4.0^{a}	7.3^{a}	14.3^{a}
0 g organic manure + 80 g *Parkia* pulp powder	2.3^{b}	4.0^{a}	5.7^{b}	11.7^{b}
0 g organic manure + 120 g *Parkia* pulp powder	2.0^{b}	4.0^{a}	5.7^{b}	11.3^{b}
40 g organic manure + 0 g *Parkia* pulp powder	2.0^{b}	3.7^{a}	5.7^{b}	10.7^{b}
40 g organic manure + 40 g *Parkia* pulp powder	2.0^{b}	3.7^{a}	4.7^{c}	11.0^{b}
40 g organic manure + 80 g *Parkia* pulp powder	2.0^{b}	4.0^{a}	5.0^{c}	10.3^{c}
40 g organic manure + 120 g *Parkia* pulp powder	1.7^{b}	3.3^{b}	5.0c	11.0^{b}
80 g organic manure + 0 g *Parkia* pulp powder	1.7^{b}	3.0^{b}	4.7c	11.0^{b}
80 g organic manure + 40 g *Parkia* pulp powder	2.0^{b}	2.7^{b}	4.0^{d}	9.0^{d}
80 g organic manure + 80 g *Parkia* pulp powder	2.0^{b}	3.0^{b}	4.0^{d}	9.3^{d}
80 g organic manure + 120 g *Parkia* pulp powder	1.3^{c}	2.7^{b}	3.7^{d}	9.3^{d}
120 g organic manure + 0 g *Parkia* pulp powder	1.0^{c}	2.7^{b}	3.0^{e}	9.0^{d}
120 g organic manure + 40 g *Parkia* pulp powder	0.7^{b}	2.7^{b}	3.0^{e}	8.3^{e}
120 g organic manure + 80 g *Parkia* pulp powder	0.7^{b}	2.7^{b}	2.3^{f}	8.3^{e}
120 g organic manure + 120 g *Parkia* pulp powder	0.3^{c}	2.3^{c}	2.7^{e}	7.7^{e}
±SEM	0.1	0.1	0.2	0.2

Means not followed by the same letter within the column differ significantly ($p<0.05$) by Duncan's Multiple Range Test (DMRT); WAS =Weeks after Sowing

Table 2: Effect of organic manure and *Parkia* pulp powder on *Sorghum* plant height and dry matter

Treatment	*Sorghum* plant height (cm)			*Sorghum* dry matter (g)
	4 WAS	6 WAS	8 WAS	
0 g organic manure + 0 g *Parkia* pulp powder	20.0[d]	40.3[c]	89.3[c]	2.1[c]
0 g organic manure + 40 g *Parkia* pulp powder	20.7[d]	41.0[c]	90.3[c]	2.1[c]
0 g organic manure + 80 g *Parkia* pulp powder	20.3[d]	41.0[c]	89.0[c]	2.0[c]
0 g organic manure + 120 g *Parkia* pulp powder	20.3[d]	40.3[c]	89.0[c]	2.2[c]
40 g organic manure + 0 g *Parkia* pulp powder	22.7[c]	45.3[b]	91.7[b]	2.9[b]
40 g organic manure + 40 g *Parkia* pulp powder	23.3[c]	44.7[b]	91.3[b]	2.8[b]
40 g organic manure + 80 g *Parkia* pulp powder	23.3[c]	44.7[b]	91.3[b]	3.0[b]
40 g organic manure + 120 g *Parkia* pulp powder	23.7[c]	45.3[b]	94.3[b]	3.0[b]
80 g organic manure + 0 g *Parkia* pulp powder	26.7[b]	49.7[b]	100.1[a]	4.0[b]
80 g organic manure + 40 g *Parkia* pulp powder	27.0 [b]	50.0[b]	99.3[ab]	4.0[b]
80 g organic manure + 80 g *Parkia* pulp powder	27.0 [b]	49.3[b]	99.3[ab]	3.9[b]
80 g organic manure + 120 g *Parkia* pulp powder	27.7 [b]	49.7[b]	98.7[b]	4.0[b]
120 g organic manure + 0 g *Parkia* pulp powder	29.3[a]	53.0[a]	101.3[a]	4.6[b]
120 g organic manure + 40 g *Parkia* pulp powder	29.7[a]	52.7[a]	102.0[a]	5.0[a]
120 g organic manure + 80 g *Parkia* pulp powder	29.3[a]	53.3[a]	103.0[a]	4.8[a]
120 g organic manure + 120 g *Parkia* pulp powder	29.7[a]	52.7[a]	100.0[a]	5.0[a]
±SEM	0.5	0.7	0.8	0.1

Means not followed by the same letter within the column differ significantly ($p<0.05$) by Duncan's Multiple Range Test (DMRT); WAS =Weeks after Sowing

Conclusion

Based on the results obtained from the experiment, the best control measure of *S. hermonthica* is the use of a combination of 120 g organic manure and 120 g Parkia pulp powder and resistant sorghum variety. Therefore, farmers in *Striga* affected areas are urged to use organic manure and *Parkia* pulp powder in addition to *Striga* resistant *Sorghum* variety.

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